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RAILWAYS;

THEIR

RISE, PROGRESS, AND CONSTRUCTION:

WITH REMARKS ON

RAILWAY ACCIDENTS,

AND

PROPOSALS FOR THEIR PREVENTION.

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ILLUSTRATED BY NUMEROUS WOODCUTS.

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ERRATUM.

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RAILWAYS;

THEIR

RISE, PROGRESS, AND CONSTRUCTION,

&c.

INTRODUCTORY REMARKS.

THE unlimited extent to which railway traffic appears likely to attain, the vast fields of enterprise it has already opened up, and its growing importance to the interests of the human race, must make every consideration affecting the construction, working, and safety of railways a matter interesting to all. Any suggestions, therefore, which may tend in the least degree to promote the general safety, cannot fail of being favourably received. That railways should have effected such vast and important changes in this country in so short a period as thirty years, through the medium of steam as a motive power, must stamp the era in which we live as one of the most enterprising in British history. Nor is the spirit

of emulation in railways confined to this country: already have the United States of America made prodigious exertions in the construction of railways; and this spirit is fast extending itself over our Transatlantic Colonies, both in British America and the West Indies, and will soon be developed in Australia. In the Spanish settlement of Cuba, railways have for some years been in existence; and both British and foreign colonies seem to vie with each other in the formation of these great conveniences for inland transport.

In our vast territorial possessions in the East, railways are about to be formed; and in the course of time the stores of wealth of our Indian Empire will be rendered more available, and the very centre of that rich and populous dominion be made accessible to all. On the continent of Europe great progress in railways has already been made, chiefly in France, Belgium, and Germany: in the last above a thousand miles are now open. A direct communication will ere long exist between Paris and Brussels; and when Paris is united to Marseilles and Havre, the advantage will be great to this country in the overland route to India. In a short time every country in Europe will be intersected with railways; and perhaps at no very distant period continuous

railways will be constructed across Europe into the centre of Asia, and even perhaps to the capital of China itself. There seems, indeed, no limit to the formation of railways. They may be the medium of removing the prejudices, and making the members of the great human family better known to each other, and thus tend to promote civilisation and preserve the peace of the world.

In Great Britain and Ireland there are already completed, or in progress, above 2800 miles of railways; and Parliament, during the recent session, has with great liberality passed bills for railways to the enormous extent of 2841 miles, with a capital of 44,322,235*l.* This may well create astonishment at the vastness of British resources; and as the money for the formation of these railways is to be expended within the kingdom, it cannot be followed with those disastrous consequences with which over-speculation has too often been attended in times that are past. Let us hope that the works that are now progressing, and still to be undertaken, will be attended with general benefit to all classes; and that while the country reaps the benefit of such unprecedented exertions, the interests of the promoters and enterprising capitalists will not

suffer. In the construction of such vast undertakings, care and precaution are obviously necessary; and nothing will tend more to their success than their judicious arrangement, and the selection of beneficial lines, and their formation in such a manner as will, with the guide of experience, make them a safe vehicle of transit; so that every one may travel by them without apprehension, and in perfect safety and comfort. This is the more necessary as every other mode of transit is fast merging into this one.

I should rejoice if this work, which professes merely to give a condensed view of the subject of railways, and of the methods by which increased safety thereon may be obtained, should tend in any degree to promote the general security in travelling.

INLAND TRANSIT.

The rapid advancement which Great Britain has made during the last fifty years is not more strikingly marked than by the vast facilities of communication opened up during that period. Down to the middle of the last century, the ancient mode of transport of goods was still continued; and most of the traffic of the country was carried on by means of pack-horses, a mode of carriage still practised in mountainous districts in many parts of the world. As the improvements of roads progressed, heavy goods came generally to be transported by waggons.

At the commencement of last century, stage-coaches had made but little progress in Britain; for we find, in the year 1706, a stage-coach advertised to perform the journey from London to York (196 miles) in four days; and, in 1712, a coach undertook to go from London to Edinburgh (about 400 miles) in thirteen days, "eighty able horses being employed on the journey." Twenty years later, the same journey was performed by coach in four or five days. The first coach was started between Edinburgh and Glasgow in the year 1678, and it took six days to perform

the journey, of 42 miles. In the year 1766, nearly a century afterwards, the same journey was accomplished by the stage-coach in eleven or twelve hours. So late as 1798 the first mail coach commenced to run between Edinburgh and Aberdeen, a distance of about 117 miles. It was twenty-one hours on the road.

Until the introduction of steam-vessels, travelling from London to Edinburgh was as serious a matter by sea as by land. Six or eight days was the common time occupied by a smack on this coasting voyage. In the year 1811 not one steam-vessel was on the river Thames; and even the passage from London to Gravesend or Margate was no trifling matter. What a contrast does the river now present! How rapid has been the advancement in steam navigation during the last 30 years! As the power of steam progressed, coach transit seemed to vie with it; and to such perfection had it reached, by improvements on turnpike roads, in the breed of horses, and by the skill of drivers, that passengers were carried fearlessly along at the rate of 12 to 15 miles an hour. Canals too, which are now so common in this country, and which were in use at an early period in the history of many nations, are but of comparatively recent introduction into Britain;

they indeed took the lead of railways, and perhaps their success retarded for a time the advancement of the latter. The first canal with locks supposed to have been made in this country, was that of Exeter in the year 1563; but till two centuries later they made little progress. The formation of the Sanky Brook into a canal, from the river Mersey to St. Helens, in Lancashire, took place in 1755, and led the way to the general use of canals in Britain. J. Brindley planned the Worsley canal, for the Duke of Bridgewater, in 1758. The Grand Trunk canal between the Trent and Mersey, 63 miles in length, commenced in 1766, was completed in 1777, and so rapid was the extension of this mode of transit, that between 1760 and 1803 no less than 2295 miles of canals were opened to the public. Equally rapid with the movement of canals and of steam navigation has been the science of railway locomotion. Though coming into full action 30 years later, it has moved on with truly amazing speed, evincing that the power of steam has effected for this country the same prodigious advancement in inland transit it has already achieved in manufactures and navigation. The immense advantage which the general introduction of railways into this country has already produced, in affording facilities for the

conveyance of passengers and goods, must be obvious to all. With a rapid and easy mode of transit, new markets will be opened up for manufactures, which must lead to the establishment of factories in heretofore neglected localities. From this impetus the vast resources of the nation will be still farther developed; the immense stores of mineral wealth so widely diffused will be made more available, and the fields of commerce, manufactures, and agriculture be enlarged and extended.

ORIGIN OF RAILWAYS. — ROADS OF THE ANCIENTS.

Railways in their present form may with certainty be considered as a modern invention, and of little more than the growth of a century It is understood that the iron railway system is entirely of British origin; and so peculiarly was it confined till recent years to this country, that it has been designated by some writers the British roadway.* But although this may be the fact,

* It has been claimed for Germany that a railway was formed in the mountainous district of Hartz, and that the principle was brought to England in the year 1676 by some miners who came to this country; but this is not much credited.

as viewed in connection with the modern principle of railway construction, still the idea of forming smooth surfaces for carriages to run upon — which is the germ of the railway system — cannot be deemed a modern invention, but is undoubtedly one of very great antiquity. It may easily be supposed that such a plan would suggest itself in very early ages, and would be taken advantage of for the transport of heavy loads. Indeed it is impossible to suppose that a people who have left us so many colossal works as the ancients have done, in Egypt and Persia, would be ignorant or not avail themselves of this method for facilitating conveyance. Very little, however, has been discovered of the practices of those nations, or of the Greeks, upon this point. But the works which the Romans have left behind them have thrown much light on the subject: for of all the works of the ancient Romans, no memorials have been handed down to posterity more enduring, and evincing more labour and enterprise, than their military roads. These seemed to have kept pace with the progress of their arms, and every country they subdued participated in the advantage; for the Romans formed their roads, it seems evident, with the twofold object of obtaining supplies and for the easier movements of their troops. Several

of the Roman roads are famed in history, and known to all readers; and our wonder of this singular people undoubtedly does increase, when we consider the celebrated Appian Way, which was carried to the extent of 300 miles from the capital. The excellence of the principle on which the Roman roads were constructed, and their prodigious durability, are attested by the fact, that parts of this famed road are yet entire, after the lapse of more than nineteen centuries. Such was the extent of roads the Romans made in Italy alone,—some of which took their names from the gates of the city,—that they have been estimated by historians at about 14,000 miles.

No principle seems more apparent in the construction of roads by the Romans, than the adoption of a smooth surface to diminish friction; and hence it may be supposed they were well aware of the advantages of smooth wheel-tracks. From the description which has been given us by the Romans, of the construction of their roads, there must have been employed a degree of skill and perseverance almost incredible. Vast labour seems to have been taken in preparing a firm foundation: sometimes arches were built, on which it was formed; sometimes piles were driven, as the basis of the road; and often, substrata of small stones,

several feet in thickness, were laid. In this country these beds of stones, of so much as three feet in thickness, have occasionally been met with. When the ground was brought towards a level, heavy stone blocks were laid for the roadway, so as to make it firm and smooth. These stone blocks have been found of different dimensions, generally of an oblong form, though sometimes a cube of about eighteen inches. Some of the Roman roads are described as being divided into two parts, for carriages going in different directions, similar to a double line of railway, and these lines of roads were separated by an intermediate footpath, paved with brick, and elevated above the carriage tracks.

STONE WHEEL-TRACKS.

Wheel-tracks formed of stone or marble, laid in parallel continuous lines, have been in use for several centuries at Milan and other parts of modern Italy; and these probably owe their origin to Roman invention. Indeed, the idea of using stone wheel-tracks till within late years was a favourite scheme for increasing the power of animal labour. Various attempts, accordingly, at different periods, have been made to introduce

this system into Britain, and several tracks of continuous stone rails, usually termed tram roads, have been constructed both in England and Scotland. The stones of such wheel-tracks are usually about a foot in width and depth, and three or four feet long. In London, and most cities, such tramways for short distances have long been in general use, and found of great advantage for ascents. A considerable portion of the road leading to the East India Docks from London is laid in this manner. There is another of some extent on a steep incline a little to the south of Edinburgh. There was an extensive stone wheel-track near Aberdeen. It was composed of granite, and was above a mile in length.

Several persons have proposed plans of stone railways for common roads and public streets on an extensive scale. The plan of Mr. Matthews of Walworth was noticed in a report of the House of Commons several years ago; and the description of another plan is also given in 1824 in vol. vi. of the Highland Society's Transactions.

The want of durability, and the expense, of stone tracks, and their comparative inefficiency for the general traffic of heavy carriages, have prevented their general adoption. As they are, however, adapted for the wheels of any kind of carriages,

such a plan of roadway is extremely useful in short distances, for increasing the power of traction. This plan has been farther extended by the introduction of iron plates, instead of stone, and cast-iron causeways have also been tried. Continuous plates of iron for wheel-tracks are now common. Among the first laid was one, in the year 1816, of some length, on an acclivity leading from Glasgow to the Forth and Clyde Canal, at Port Dundas. It was ascertained by experiment, when executed, that one horse could take up a load of 3 tons, in a common cart weighing 9 cwt., without any apparent difficulty.

A plan somewhat similar was proposed by a German at Munich, to lay an iron plate on the upper surface of the stone-track, in order to diminish the friction and to prevent the abrasion of the stones into ruts by the wheels.

It must be obvious to those who consider the science of locomotion, that it would have made slow progress indeed had no other plan than that of stone wheel-tracks been devised. The great step in advancement was the introduction of the wooden tramway, with carriages adapted for it. This had many advantages over the wheel-track: not only was the friction still farther diminished, but the road could be kept easier free from ob-

structions. The application of this method of traction necessarily led to its improvement. We, who are accustomed to the beautiful roads which a Macadam* has introduced, can form but an imperfect idea of the immense advantage such a plan must have presented to aid animal labour; but the contrast must have been striking in drawing wheels over smooth surfaces, instead of through the deep ruts of the rude common roads of a century back. When it is considered, too, that the ordinary friction on a level railroad is only about $\frac{1}{10}$ to $\frac{1}{7}$ of that of a common road, we perceive the advantage of the former in a commercial point of view, as a horse can draw several tons more on it than on the latter.† Thus a much greater weight could be moved with the same force on the rail than on the road; but on an ascent, the same disproportion does not continue to exist; for the additional weight of the load of the carriage on the rails comes into operation in ascending the incline, and, as the force of gravity

* Before Macadam's time the inhabitants of Holland had long enjoyed the benefit of well-formed and smooth roads. These are made of small bricks bedded in lime.

† The usual estimate of the draught of a horse on a common road is from 15 to 30 cwt., exclusive of the weight of the cart, 4 or more tons on a plate rail tramroad, and from 15 to 20 tons on an edge railway including the waggons.

is in proportion to the load, the opposing resistance diminishes the effect, or positive gain. The important principle in railway construction becomes therefore, at once apparent—that the more level the way, the straighter and fewer the curves it presents, the less will be the loss of power.

RAILWAYS INVENTED.

The characteristic distinction of the railway from that of wheel-tracks or stone tramroads is, that the railway is formed of parallel rails or bearers laid on a level, or as near a level as possible; these rails being placed at a uniform distance apart, to suit the gauge of the wheels of carriages adapted purposely for the track or way, and having a margin, or what is termed a flanch, to guide them. When cast-iron plate rails were invented, the flanch was made on the rail itself; but some time after the introduction into the country of cast-iron wheels, which is understood to have taken place about 1754, the plan was reversed, and the flanch was cast on the wheel.

It is not accurately ascertained when railways on this principle were first introduced into Britain. They were originally termed tram or dram roads,

or waggon-ways, the name tram-way being applied both to railways of this description and to stone wheel-tracks, though it is now commonly given to the latter. They were at first, probably, nothing but continuous parallel logs of wood, with a smooth surface. It is generally understood that wooden railways were first applied as a substitute for common roads at the collieries, between the years 1602 and 1649, for the purpose of more easily transmitting the produce of the coal-fields and other minerals from the mouths of the pits to the place of shipment, and of enabling the horses to draw greater loads.

A description is given of a railway in 1766, then in use near Newcastle-on-Tyne, whereby the carriage is so easy that one horse will draw four or five chaldrons of coals. For more than a century these railways were made of the most simple construction. A flat rail or tram way of timber was made use of, resting on wooden sleepers laid across the road. Probably, at first, single lines were only in use; subsequently, thin plates of malleable iron were laid upon the surface of the wood, to diminish still further the friction.

CAST-IRON PLATE RAILS.

Railways continued much in this form for about a century, and little attention was bestowed on their improvement till the year 1738, when rails wholly of iron are said to have been tried at Whitehaven, as a substitute for wooden ones; but this attempt did not succeed. Some years ago Mr. R. Stevenson, C. E., Edinburgh, took some pains to investigate the subject; and he observes, in "Notes in reference to Essays on Railways presented to the Highland Society, in 1819, by Mr. Scott and others," that he had reason to believe that the introduction of rails wholly made of iron did not take place till the year 1766 or 1768, and that he had ascertained that 5 or 6 tons of rails were cast at the iron-works of Mr. William Reynolds at Colebrook Dale in Shropshire, in November, 1767. From an account of the introduction of iron rails at these works, which was given by Mr. Hornblower in a report on roads, made to the House of Commons in the year 1811, it appears that a wooden railway was in use there until about this date, when it was resolved to lay down cast-iron plates 5 feet in length, 4 inches broad, and a quarter of an inch thick, with three holes in each for nailing

to the wood. These rails must have been very imperfect, having no guide-flanch, although it was soon after introduced. Mr. John Curr stated, in 1797, in the preface to his work*, that the making use of cast-iron rails, and corves or coal waggons, was the first of his inventions, and was introduced by him at the underground works of the collieries of the Duke of Norfolk, near Sheffield, about 21 years before he wrote. This would make the date of his introduction of cast-iron rails about 1776; but, as before observed, rails made wholly of iron seem to have been previously in use, but whether with a flanch or not, appears doubtful. Mr. Curr describes the rails he made use of in 1797 as cast-iron plates 6 feet long, three inches broad, and half an inch thick; and the margin, or ledge, which was half an inch thick, and rounded on the top, stood two inches high above the plate. *Fig.* 1. shows the end view of Mr. Curr's plate rail. He remarks that these rails were considered a great improvement on the common iron-plated wooden tram-road; and his plan was imitated, and applied at most of the collieries for three successive years.

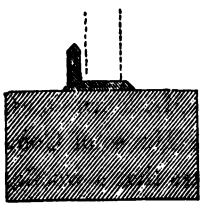


Fig. 1.

* "Coal Viewer's &c. Practical Companion:" London, 1797.

CAST-IRON EDGE RAILS.

About this period more importance appears to have been attached to the railway principle of traction, which hitherto had been confined entirely to the carriage of minerals. It has been stated that the first public railway in England was the one constructed at Loughborough, in the year 1789, under the direction of the late Mr. William Jessop, engineer; and to him is ascribed the first introduction of cast-iron edge rails (for which a patent was granted) with flanches cast upon the tire of the wheels to guide them on the track, instead of having the margin or flanch cast upon the rail itself, as described by Mr. Curr.

The upper surface of Mr. Jessop's rail was made level, section, *fig.* 2., and the under part of an elliptical form, front view, *fig.* 3., now termed the fish-bellied rail. When first introduced, chairs or pedestals, as now employed to support the rail, were not used; but the rails are described as having a flat base projecting outwards on each side of the end of the rail, through which there were square holes for the bolts to pass to fasten them to the sleepers.


Fig. 2.

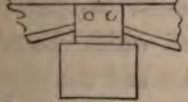


Fig. 3.

Subsequently the ends and joinings of the rails were supported by means of iron chairs placed on square pieces of timber, which gradually became superseded by stone props or separate blocks of stone. These are stated to have been first employed, in 1797, by the late Mr. Barns, at the Lawson Main colliery railroad, near Newcastle-on-Tyne. Stone blocks were likewise used in the year 1800, by Mr. W. Outram, engineer at the railway of Little Eaton in Derbyshire. Instead, however, of employing Mr. Jessop's edge rail, he used a plate rail, *figs.* 1. and 7., with the guide flanch for the wheel cast on it, as, notwithstanding the advantages of the edge rails which Mr. Jessop had introduced, the plate rail continued long in general use. The next form of an iron rail proposed is one described in the patent granted, in 1803, to Josiah Woodhouse, C. E., Leicestershire. He proposed a form of rail or

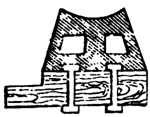


Fig. 4.

plate to be made of cast iron, the upper surface of which should be concave, (*fig.* 4.) and the width of the rail or plate to be increased or diminished to suit the size of the wheel of the carriage. The reason he stated for adopting a concave form of rails was, that while the wheels of carriages were kept in the right direction,

they admitted of getting upon or from them with facility. These rails were chiefly intended to be imbedded in common roads.

Perhaps the first distinct account made public of an edge railway of any extent was by Mr. Wyatt, in 1802, who gave a description of a railway of considerable extent, constructed by him, at the slate quarries on the late Lord Penrhyn's estate, near Bangor, North Wales. He gave a farther account of this railway in a letter to the editor of the "Repertory of Arts," dated Lime Grove, April, 1811, in which he mentioned that this railway still continued in its original form, excepting the sills and beds; these had been first made of wood, but he had found it an improvement to make the chairs of cast iron. In *Fig.* 5., *a* is a section of Mr. Wyatt's rail, which was made in lengths of 4 feet 6 inches. An iron tenon, *b*, was cast on each end of the rail, 2 inches long, which was made to slide into *c*, a dove-tailed block: *d* is the wheel. This form of rail does not appear to have been introduced at the collieries in the North of England, where edge rails, as represented in *fig.* 3., or plate rails, were chiefly employed.

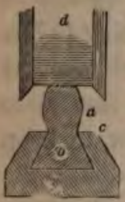


Fig. 5.

PLATE RAILS IMPROVED.

The next proposal for an improvement on iron rails emanated from Mr. Charles Le Caan of Llanelly, in Wales, who, in the year 1808, received a premium of twenty guineas from the Society of Arts for an improved tram-plate for carriages. The principle of this invention was dispensing with spikes or nails, commonly used in fixing the plates to the blocks, by having plugs or stops cast at certain distances on the rails.

Fig. 6.

Fig. 6. is an end view. He describes the tram-plate as 3 feet in length, with a flanch on the outer edge half an inch high; the sole, or bed, for the wheel, about 4 inches; and the metal itself three quarters of an inch thick; the rail weighing 14 lbs. to the foot. The plates were fastened together by means of a tenon and mortice joint, each piece having a corresponding bevel sufficient to keep the ends from rising up. He pointed out the advantages of the plan to be, that, when the blocks were put in their places, they would not sink beyond the intended level; that driving plugs

and spikes was rendered unnecessary; that the breakage of the rails was avoided, and that the carriage wheels were not obstructed by the heads of the nails.

This invention clearly points out the progress which rail or tram roads had made at the commencement of the present century; and that this subject at that period was attracting more attention may be seen from the communication Mr. Le Caan made to the Society, in which he remarked that railroads were daily increasing, from the great advantages they afforded in mining, mineral, and agricultural districts.

There are still in existence in different parts of the kingdom railroads of the most primitive construction, which may enable one to judge of what importance were the improvements made by Mr. Le Caan.

In the year 1801 an act of parliament was obtained for making the Surrey iron railway. It extended from Wandsworth, on the Thames, near London, to Croydon, a distance of 6 miles, and the cost of its construction, with a branch to Carshalton, was 60,000*l.* The same railway was extended in the year 1803, from Croydon to Merstham, Reigate, and Godstone, above 15 miles, and at a cost of 90,000*l.* As the tram-way exists in

its original state from Wandsworth to Croydon, it may be contrasted with the London and South Western railway, which crosses it about a mile from Wandsworth, affording an example of the advancement made in the last forty years.

The Surrey tram-way was formed at a period before edge rails had come into general use: hence cast-iron plate rails were adopted. These are made in pieces 3 feet in length, $4\frac{1}{2}$ inches broad, and half an inch thick, with an upper vertical guide flanch, about 2 inches. Both the upper flanch and the under ledge are slightly elliptical, for the purpose of strengthening the plates.

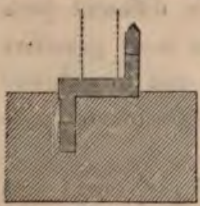


Fig. 7.

Fig. 7. shows a transverse section of a plate and block of this kind. On the Surrey tram-way the blocks are, however, merely rough stones. A block is placed under every joining, and the ground is made up nearly level with the top of the rails. The plates are fastened to the blocks by means of a spike driven into a wooden plug, there being a notch or groove in the end of each plate, so that one spike holds down the two plates. The whole work is of a coarse description. The plates, being imperfectly held down, are easily shaken, and the rails present many

inequalities from the sinking of the blocks, which has led to the breakage of the plates: the friction must, therefore, be considerable. The usual load which a horse can draw on it is, however, said to be about four tons. The carriage wheels used for the waggons (which are entirely drawn by horses) are about two feet in diameter, and the tire of the wheels $1\frac{1}{2}$ inches.

There are two lines of rails laid down, the gauge of which is four feet, with an intermediate space of five feet. Notwithstanding the general levels of this tram-way being good, and that it affords facilities for conveying agricultural produce to London, and the return of manure to the country, there is not much traffic on it, being superseded by the more efficient system now in use.

It cannot be wondered at that the public opinion, with such an example as this, should have been for several years unfavourable to railways. Plate railways, however, continued for long in common use after this one was made. In the year 1808 an act was passed for the construction of a tram-road $9\frac{1}{2}$ miles in length, of a similar description, between Kilmarnock and Troon in Ayrshire, being the first public railway that was formed in Scotland. It was a double line of way laid with a plate rail bedded on stone

blocks, similar to the Croydon tram-road. Another railway projected about this period, 1810, was one from Glasgow to Berwick. It was surveyed by the late Mr. Telford, and the expense estimated at 2926*l.* per mile; but it was never commenced.

MALLEABLE IRON PLATE RAILS.

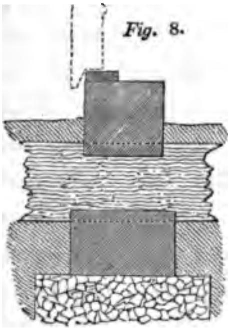
The plate iron rails were made of cast iron till about the year 1824, when wrought iron came to be adopted. The chief recommendation of plate rails must have been their cheapness of formation, as edge rails required a greater quantity of material; but the objections to the former arising from the friction of the wheels against the upright flanch, the broad surface of the plate collecting obstructions on it, the numerous joints interfering with the action of the wheels, and the constant repairs required when heavy traffic was carried on, must have always detracted from their utility.

Plate iron rails of other forms have occasionally been used in this country. In the United States a very simple plate rail of malleable iron is in common use, consisting of iron bars 15 feet long, $2\frac{1}{2}$ broad, and from $\frac{1}{2}$ to $\frac{5}{8}$ of an inch in thickness, fastened to a wood or stone rail. The flanch is

placed on the wheels, as in the edge rail. Railways are worked with locomotive engines on this kind of rails, with considerable success, at moderate velocities, and, from the abundance of timber and the little outlay required for iron, the adoption of this plan becomes an object, having the advantage of the materials on the spot. The first railway understood to have been constructed there was in the year 1827, called the Quincy railroad, four miles in length, from a granite quarry to the shipping port of Neponset. Since that period railways have been extended with even greater rapidity than in this country, and are still rapidly advancing. It is said that about 5000 miles of railways have been made; but as many of these have only a single line of way, are of an inferior construction, and intended for slow speed, they can hardly be compared with the costly undertakings in this country. It may easily be surmised that, in so many miles of railways, many plans must have been tried. On some of the lines, rails similar to those used in this country are adopted; on others the iron plate rails have in some instances been laid upon continuous blocks of granite; but the more general plan, however, is to place them on longitudinal wood rails. The annexed sketch (*fig.* 8.) shows the trans-

verse section of the Saratoga railway, constructed in the latter way, a railway of this kind being considered well adapted for swampy districts, and where forests abound. The bed of the railway is first formed with parallel trenches, 18 inches square, filled with small stones, which serve as a drain to keep the timbers dry, and cross trenches are made in a similar manner, and to attain the same object, under the cross sleepers. Upon the parallel trenches, along the line of the railway, are first placed longitudinal timbers of yellow pine, with a scantling of 5 or 6 inches by 8 inches, and to these, at three feet apart, are firmly secured transverse wooden sleepers of white oak, (cedar, or locust, or other wood,) sometimes 6 inches square, and at other times with a scantling of 8 or 10 inches broad, and 10 inches deep; and, lastly, the longitudinal wooden runner, 6 or 8 inches square, which forms the line of rails, is fixed; upon which the plates of iron of the size previously stated are laid and fastened with iron spikes with the heads made flush with the plate. On other lines, as the New York and

Fig. 8.



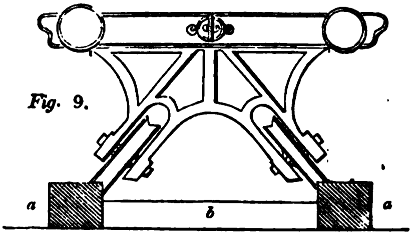
Boston, the under timbers are dispensed with, and transverse sleepers, 7 feet long and 8 inches square, are laid, upon which the longitudinal timbers are fixed, surmounted with the plate rail. On the Philadelphia and Columbia railway, 82 miles in length, under the management of the state, several plans have been tried experimentally. On the Baltimore and Ohio railway, several miles of rails are laid with granite sills, or a continuous curb, in pieces from 5 to 9 feet long, 15 inches broad, and 8 inches thick, upon the inner edge of which the iron plate is spiked down to tree-nails of oak: on other lines the blocks are one foot square, and rest on a stratum of broken stones. A short distance of the Quincy railway is likewise laid with stone blocks. Some of the rails, from the sharpness of the curves, are connected together with iron ties. It has been found necessary, to prevent impairing the efficiency of this kind of railway, to place the iron rails more towards the centre of the blocks.

WOOD RAILS.

In this country the system of wooden railways has lately been revived by Mr. Prosser, chiefly

to take advantage of his guide wheel, and a few miles of timber rails have recently been experimentally laid down at Wimbledon Common. The rails (*fig.* 9. *a, a,*) are formed of square blocks of wood,

Fig. 9.



beech or hard wood, without any protecting iron plate, 9 feet long, and 6 inches square, attached to wooden sleepers *b*, and secured by wooden wedges, forming one great frame of longitudinal and cross sleepers. A part of the timber has been subjected to Mr. Payne's, and a part to Sir Thomas Burnett's patented process for increasing the durability of timber. Mr. Prosser states that the advantages to be derived from the use of his patent guide wheels in connection with the wooden rails are, that, from the greater *bite* wheels have on wood than on iron, a steeper class of gradients can be ascended, that shorter curves can be taken with safety, and that the general liability of carriages to run off the line is di-

minished, to which he adds, the cheapness of the original construction. Mr. Prosser has done away with the flanches on the carriage wheels, but considers that the advantages derived will be greater from the substitution of a guide wheel for the flanch on the bearing wheels, and that the invention is equally applicable to iron rails as to those of any other material.

PATENT CAST-IRON EDGE RAILS.

Although many plans were devised after the introduction of the edge rail into this country, no very decided improvement took place till the year 1816, when Mr. Losh, of Wallsend, and Mr. George Stephenson, who was at that time at Killingworth, obtained a patent for a cast-iron rail, which was at the time deemed an improvement over the common mode. The practical evil then existing in the system of laying the rails was the obstruction which the waggon wheels met with at the joints, and from the shock that was given, the rails were displaced and broken. This led to different plans of rails and chairs being proposed as a remedy. The object of the patent was to fix the rails immoveable in the chairs. The

rails were joined by what is termed a half-lap joint, with a pin or bolt which fixed them. The object intended to be effected was, that the end of one rail should not rise above that of the adjoining one, and securing the rails from yielding in the event of the block sinking.

Fig. 10. shows the joint and block of the patent rail.

Fig. 11. Transverse section of rail.

Fig. 12. The plan.

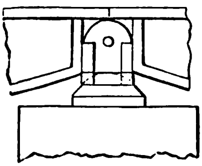


Fig. 10.

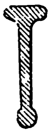


Fig. 11.

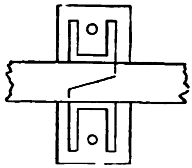


Fig. 12.

A somewhat similar form of a rail was proposed by Mr. B. Thompson, and tried at the Brunton and Shields railway. In this plan the chair had only one cheek or side, and the rail was fastened to the chair by means of a screw-bolt. *Fig.* 13. is a transverse section of the rail chair and screw-bolt. This plan of fixing with screws was found to be attended with inconvenience in practice, wedges or keys being preferred.

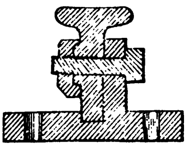


Fig. 13.

MALLEABLE IRON-EDGE RAILS.

The first decided improvement, however, in the construction of iron rails suitable for rapid speed, was the substitution of malleable iron instead of cast iron; for it must have been obvious that the great desideratum was to obtain a rail of sufficient strength. Mr. N. Wood states, that malleable iron-edge rails were first tried about the year 1803, at the Wallbottle Colliery, near Newcastle-on-Tyne, by Mr. C. Nixon. The rails made use of, were short bars, only a few feet in length, joined together with one pin, by a half-lap joint, the end of the one rail projecting two or three inches beyond the end of the adjoining one; but at this time the preference was given to cast-iron rails with a broader surface.

According to a report made by Mr. R. Stevenson of Edinburgh, dated December, 1818, malleable iron-edge rails were first introduced about the year 1810, at Lord Carlisle's coal-works, at Tindell Fell, Cumberland. At the time he wrote, he observed, that 3½ miles of malleable iron rails had been in use for eight years at that coal-work, where there were also two miles of cast-iron rails, and the malleable iron was

found to answer the purpose in every respect better. This statement was corroborated by a letter from the works, dated May, 1819, in which it is mentioned that malleable iron rails had been laid down for eight years without requiring alterations, while the cast iron were attended with a daily expense from breakage. Mr. Stevenson seems to have been strongly impressed, at the period he wrote, with the superiority of malleable iron for the making of edge rails. He remarked, that the plate rail, then so much used, not only induced greater friction, but tended to clog the wheels; that the application of malleable iron edge-rails, instead of cast iron, would be attended with most important advantages to the railway system, and that he gave a decided preference to malleable iron, formed in bars from 12 to 15 feet in length, with flat sides, and parallel edges. Subsequent events have fully proved the truth of this conjecture; but the general opinion at the time was against the use of malleable iron for rails, on the ground of its greater liability to oxidation, and of the mode of rolling rendering them fibrous, and liable to laminations; and Mr. Wm. Chapman, in his report on the Newcastle and Carlisle railway, 1829, was unfavourable to malleable iron, on these grounds.

The application, however, of malleable iron rails was extremely limited until after the year 1820, in October of which year Mr. John Birkenshaw, of the Bedlington iron-works, obtained a patent for an improvement in their construction. Previous to this patent, the section of the rails was either a square or an oblong, or sometimes a bridge form of rail was used. In the specification of the patent, the invention is described to be "malleable iron bars formed in prisms." The upper surface of the bar, on which the carriage was to run, was to be made slightly convex, to reduce the friction, and the under part to rest on the supporting blocks, chairs, and sleepers. The wedge form was proposed, he states, because the strength of the rail is always proportioned to the square of its breadth and depth; and that hence this form of a rail possessed all the strength of a cube equal to its square; he also adds, sufficient strength might still be retained, and the weight of the metal further reduced, by forming the bars with concave sides. From the sketch Mr. Birkenshaw gave of his rails, in 1820, they differ little from the single parallel rails now used, except in the form of the bar itself.

Although this patent invention did not present much apparent novelty, still the attempt to intro-

duce a scientific principle of construction, led the way to the vast and endless variety of forms of iron rails which have subsequently been introduced, and in which much ingenuity has been displayed. For many years after this patent was taken out, public opinion seems to have been in favour of the "fish-bellied edge rails," as introduced by Mr. Jessop; and accordingly this form of rail was most generally used. We have seen that Mr. George Stephenson, in conjunction with Mr. Losh, had taken out a patent for an improvement on the form of rail in 1816; and on the Stockton and Darlington railway, where the former gentleman, who has been justly considered the father of the locomotive system of traffic, made his first appearance as a railway engineer, the original rails, probably laid down in the year 1821 or 1823, were of the fish-bellied form, only 28 lbs. to the yard.

This shape of rail was afterwards made in malleable iron, and adopted on several railways. In the year 1829, Messrs. Losh, Wilson, and Bell obtained another patent, for a mode of joining rails of this form without a pin, as proposed in Mr. G. Stephenson's former patent; and their patent rails were laid down on the Newcastle and Carlisle railway, in 1829, and in other places.

It may be observed how slow was the progress

of invention in railway construction, until the patent for the malleable iron rail was obtained, in 1820; indeed it may be said, that till then no material alteration of the principle upon which railways had long been constructed took place. At this period, indeed, the vast capabilities of the railway system were hardly surmised; it was confined nearly to its original application for traction at collieries; for the whole railway Acts for the preceding twenty years were only twenty. At this time the Stockton and Darlington railway company had not assumed a public form; for it was not till 1821 that they obtained their first Act, to construct a tram-road from Stockton on Tees to Witton Park Colliery, with several branches, for which a capital was proposed of £82,000, in £100 shares, besides a loan of £20,000. In 1823 and 1824, the powers of the company were further enlarged by other acts. At this period the number of railways in the United Kingdom was considerable, when those at coal and iron works were added: and these were all worked either by horse power or by gravity.

One of the best railway engineers, about this time, in England, was the late Mr. William James of Warwick, who planned the first railway of any length in England, the Stratford and

Moreton railway, for carrying coal and agricultural produce. It was completed in 1821; was 18½ miles, in length including branches, and was also worked by horses.

Another individual who, about this period, displayed much prescience in the railway system, was Mr. Thomas Gray of Leeds, who, from a work he published in 1820, entitled "A General Iron Railway," has been considered the projector and founder of the present iron railway system. It has been stated that Mr. Gray, like many other projectors, has reaped no advantage from his useful suggestions, which is more to be regretted, when so much wealth has been acquired by railway schemes. No one, a few years ago, or in 1820, could have forseen the giant strides which the system of railway transit, in so short a period, could have made; and the spirit and enterprise which have been displayed in carrying out their construction are beyond human calculation. All this success has, however, sprung from one single circumstance — the invention of an efficient impelling force; for without a powerful prime mover, of how little utility the ferreous system for passenger traffic would really have been, is at once ascertained by contrasting the railways at that time in use with those at the present.

Not thirty years back, large sums were expended in the construction of railroads for horse traffic, on which passengers considered it a boon, from the cheapness of the fares, to be drawn in carriages, by one horse, at the rate of 8 or 10 miles an hour. So late as 1826, a railway Act was passed for constructing a cast-iron edge railway, worked by horse power, between Edinburgh and Dalkeith, with branches to the coal-works, which was opened for traffic in 1831, and it is still worked in the same manner. This railway is indeed about to be remodelled and extended, for locomotive transit; for at present, from the lightness of the rails originally laid down (which were fish-bellied, about 28lb. per yard, on stone blocks and chairs), and from the short radii of several of the curves (600 feet, or less than one eighth of a mile), this railroad is unfit for locomotive engines.* Its alterations will, however, be attended with much expense, and may even be imperfect when completed. It would be more advantageous perhaps to leave it as it is, for

* On railways, the lengths are described in miles, chains, yards, and feet. One mile contains 5280 feet, 1760 yards, or 80 chains. A chain is subdivided into 100 links; and the fractional part of a chain is expressed decimally, as 10·5, which is 10½ chains, a little more than one eighth part of a mile; 10·75, which is 10¾ chains, &c.

coal traffic, and construct a more direct line of railway.

Other railways at the same period were constructed for horse power, some of which have already been altered to suit locomotive engines. So late as 1831, an act was obtained for constructing the Whitby and Pickering railway for horse traffic*: several small railways are still worked with horses. It has indeed been well remarked, that excepting on account of humanity, little comparative advantage, so far as passengers are concerned, could be gained by the use of railways worked with horse power, over the old mode of travelling by stage coaches, and even this is doubtful.

RIGIDITY OF MALLEABLE IRON RAILS.

It would be tedious to describe the multiplicity of forms which have been proposed of late years for iron rails: one indeed might be puzzled, amongst the variety, to determine their relative merits, and

* On this railway, the average speed at which the carriages are drawn, is 11 miles an hour; and at this speed, one horse will draw a carriage weighing 3 tons, and about 30 passengers; in all, 5 tons.

to fix on that which is best. It is important, however, for understanding properly the construc- of railways, to have a clear conception of the different methods which have been adopted in laying down the rails on different railways.

After the formation of the road, and when the banks have become consolidated, the great principle to be kept in view, where steam is the motive power, is the application of malleable iron rails, in such a manner that they shall have sufficient stability for heavy carriages to run upon them with velocity and safety.

For a long time after the introduction of malleable iron rails, the plan of supporting the rails at intervals on props, as the piers of a bridge, as shown in *fig.* 14.,

Fig. 14.

was continued, and is still the method adopted in the great majority of the railways in this country. The iron rail being obviously liable, between these supports, to be depressed or deflected, when heavy loads passed over it, and, if it possessed much elasticity, to become dangerous, as acting like a spring, it therefore became an important point to give it such a form, and such strength,

that the undulations it might be subjected to, would not communicate a shock and disturbance of the joints, and add to the amount of friction. A great deal has been written on this important subject; although it might have seemed an easier thing to adopt another plan entirely, where the deflection of the rail would be merely nominal, than to endeavour to correct a plan, in the principle of which there was an inherent defect.

The form of rail, it has been shown, which was long in general use, and preferred, was the elliptical, which, from the upper edge being level, and the under part swelled out, was supposed to possess greater strength. Of this shape were the malleable iron rails first laid down on the Liverpool and Manchester railway, weighing only 35 lb. per yard. *Fig.* 15. is the elevation of this rail and chair.

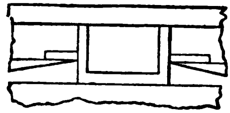


Fig. 15.

Fig. 16.

Fig. 16. is the section at the middle of the rail.

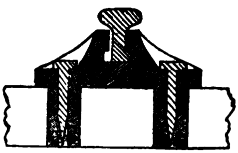


Fig. 17.

Fig. 17. is a section through the rail and chair.

These rails were, however, soon ascertained to be too light; and heavier ones, of the same shape, were adopted.

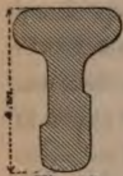


Fig. 18.

Fig. 18. is a section of the 50 lbs. elliptical rail, laid down on the same railway. It was 4 inches at the extreme depth in the middle; and 3 inches at the bearings.

This shape of rail continued to be commonly used on railways until the year 1835, when the Directors of the London and Birmingham Railway Company requested Mr. P. Barlow, F.R.S., to visit the Liverpool and Manchester railway, with the view to advise the Board as to the weight of the rails, the description of chairs and fastenings, the distance of the supports, and the size of the blocks, to be adopted. In order to ascertain accurately, by experiment, the strain which a load in rapid motion produces upon the rail, or bar of iron, over which it passes, compared with the known strain produced by an equal load quiescent, Professor Barlow used, for the purpose of measuring the exact amount of deflection, an instrument which he called a *deflectometer;* consisting of a system of well-balanced levers, with a registering index: one point of the lever being applied under the centre of the rail, the greatest deflection the rail sustained, during the passage of a heavy load over it, was distinctly indicated. The

experiments were conducted at the Liverpool and Manchester railway, with rails of different forms, placed on bearing-blocks, at different distances apart; and the results were given to the public in two reports:—

He stated that he had proved, "that while blocks and fixings are secure, the strain from a passing load is but little in excess of that from a quiescent load, or as ·089 is to ·079 parts of an inch; whereas the effect on the joint-ends amounts to ·121 inch, being an excess nearly of 40 per cent.; but this excess of strain at the joints was in part due to the looseness of the chair and block; for while the deflectometer only showed the amount of deflection when the load passed over, the lurching of a waggon, from some irregularity, would indicate double the amount. If the deflection per ton be taken at ·0050 inch, with 33-inch clear bearings, 3 tons at 45-inches bearings gave ·0314 when at rest, and ·0353 when in motion; showing that, when every thing is well fixed, the strain is nearly the same, and that each rail is only pressed with half the weight of one pair of wheels."

This result, it must be obvious, is what *à priori* might be expected; and as the joints are most affected by the shock, the plan of reducing the

number of the joints, or increasing the length of the bars, from the first forms of rail which were used, was long ago adopted. Still, however, as the vertical deflection of the bar increases the disturbance of the joints, it becomes a point of the greatest practical importance to fix the best distance to place the props apart; and it would therefore have been of much use had this point been conclusively fixed; in place of which, the result of Mr. Barlow's experiments seems to be, that he considered that, by increasing the section of the bars proportionably to the distance of the props, the two might go on *pari passu*; — that, in practice, it will be found more important to increase the weight or section of the rails, and to decrease the number of the bearings *; — that there were limits, however, even as to this, which could not be conveniently passed; for if the bearings were much extended, the breadth of the rail must be so much increased as to require a weight of iron altogether inadmissible; or the depth must be increased in the same proportion as the length of the bearing, which is impracticable; or if the bearings, on the contrary, were too close, the requisite quantity of iron in the bar may be so

* Lieutenant Lecount, R.N., wrote against lengthening the bearings, in his work, 1836.

small as to give a very unsatisfactory section;—that it is still, therefore, a question which is the best length to adopt, or whether different lengths might not be employed, according to local circumstances;—that, so far as mere present outlay is concerned, the plan which will cost the least money, can only be known when the price of stone, expense of labour in laying, and price of iron, are given; but looking to future expenses, he would certainly prefer the larger bars and longer bearings;—that it was however useless, restricted as above, to examine any distance of bearings less than three feet, and more than six;—and with this restriction, he thought that such increased thickness might be given to the iron as would enable it, even with the props farther apart, both to meet the vertical pressure, and resist the lateral strain, when the rails are laterally deflected at the outer sweep of curves; for the deflection of the longer bearings, although greater than the shorter, was not to a large amount.

Mr. Barlow came to the conclusion, that the strength of a bar should be double that of the mean strain, or load. In his first report, he thought from 10 to 20 per cent. would be sufficient; that is, for a 12-ton engine, as the weight is at present distributed, a strength of 7 tons

would be ample provision; and with greater accuracy of construction, a less strength would suffice; or rather, allowing the same strength, an engine of 14 or 16 tons might be passed over with greater confidence. Thus, for 12 tons' weight, with a velocity of about 35 miles per hour, 7 tons would allow a surplus strength of 16 per cent. beyond double the mean strain. The deductions from his experiments led him to recommend that the section of an iron rail for a 5-feet bearing, with strength 7 tons, should not exceed 5 inches in depth; that the head ought not to be less than 2·25 lbs. per yard, and be 1 inch in depth; that the whole weight at the sections should be 67·4 lbs. per yard; the thickness of the middle rib, ·85 inch; depth of bottom web, 1·66 inch; and breadth of ditto, $1\frac{1}{8}$ inch; that the deflection of such a rail, with 3 tons, would be ·064 inch.

Fig. 19. is the section of a rail of this shape, laid down, on one railway, 60 lbs. per yard. For bearings of less width, he did not reduce the weight or size of the head, but kept it at the same section, decreasing the whole weight and depth of the rail: thus for a strength 7 tons, with a 3-feet bearing, the whole weight

Fig. 19.

was 51·4 lbs., whole depth $4\frac{1}{2}$ inches, depth of bottom web 1 inch, breadth 1·25 inch, thickness of middle rib ·6 inch, deflection with 3 tons was ·024 inch.

Section for a 3-feet 9-inch bearing: whole depth $4\frac{5}{8}$, depth of bottom web 1 inch, breadth $1\frac{1}{2}$ inch, thickness of middle rib ·75 inch, of whole weight 58·8 lbs. per yard, deflection 3 tons ·037.

Section for a 4-feet bearing: whole depth $4\frac{3}{4}$ inches, depth of bottom web 1 inch, breadth of ditto $1\frac{1}{2}$ inch, thickness of middle rib ·8 inch, whole weight 61·2 lbs. per yard, deflection with 3 tons ·041 inch.

Section for a 6-feet bearing: whole weight 79 lbs. per yard, whole depth $5\frac{1}{2}$ inches, depth of bottom web $1\frac{1}{2}$ inch, breadth 1·66 inch, thickness of middle rib $1\frac{1}{8}$ inch, deflection with 3 tons ·082.

Such is the form and section of rail recommended by Mr. Barlow; and it is seen, from the above description, that although he preserved the same strength and resistance in each of the rails, the important fact is brought out, that the longer bearings are less stiff than the shorter, showing, as he admits, that the idea of greatly increasing the distance of the bearings must be given up.

Mr. Barlow's report has shown that it was doubtful if any additional strength was gained,

in a given weight of iron, by the elongation of the centre rib, while it was inconvenient in other respects. The fish-bellied or elliptical form of rail has therefore been entirely given up, excepting on railways where it had previously been adopted. The rails which are now in general use, are either the single parallel rail, as proposed by Mr. Barlow and others, under the various forms called T rails, or what have been termed double parallel rails, like a double T, having a top and bottom flanch parallel with the ground.


Fig. 20.

Fig. 20. is the section of a single parallel rail of 50 lbs weight per yard, which has been used on several railways.

Notwithstanding that Professor Barlow expressed a strong opinion in favour of the single-flanched rail over the double,—that he could see no advantage the latter possessed to compensate for its actual and obvious defects, that he considered it inferior in strength and convenience in fixing, and that the advantage it was supposed to possess, namely, that it might be turned when the upper table was worn down, was impracticable, and that he saw no advantage in the broad bearing,—still the double-headed rail, in practice, has almost

entirely superseded the single one: whether the adoption of the double one arises from affording greater convenience to the rail layer, and facilities for keying it, and the advantage of having the power of reversing it, and selecting the best side, or from the manifest advantage of a broad bearing to the rail, — this form is now generally preferred.

The Liverpool and Manchester Railway Company has of recent years adopted a double parallel rail of a peculiar section; not admitting, however, of the power of turning it. The object to be attained in adopting this shape, is stated to be, that by having the part of the rail upon which the flanch of the wheel acts, of the same outline as the flanch itself, greater strength is given to the rail, while the other edge of the rail is lightened. These rails have been laid down at 60 and 75 lbs. per yard. *Fig.* 21. is a section of the 60 lbs. rail.

Fig. 21.

The more common and useful form of a double parallel rail, is when the segmental outline is the same at top and bottom: for although it cannot be denied that the weight of the bottom flanch does not add proportionably to the strength of the rail, nor even that the power of turning it is at all times practicable, — yet there cannot be any doubt that

this form, for railways constructed on separate blocks and sleepers, presents many advantages; and besides, as the cost is nearly the same for a rail with the top and bottom flanches alike, with that where the bottom web is somewhat lighter, no hesitation can exist in preferring the former, however much theoretical deductions may mystify the subject.

Fig. 22. is the section of a double parallel rail, weighing 75 lbs. per yard, which has been laid down on the London and Birmingham, Eastern Counties, South Eastern, Edinburgh and Glasgow, and many other railways.

Fig. 22.

The whole depth is 5 inches, the top and base are the same sections, 2·5 inches, the thickness of middle rib is about $\frac{3}{4}$ of an inch, or less.

Fig. 23. is the section of a double parallel rail; which has been used upon the Grand Junction and other railways, weighing 62 lbs. per yard; whole depth, 4·5 inches.

Fig. 23.

Fig. 24. is the elevation, on a smaller scale, of a double parallel rail, about 65 lbs. per yard, of which the whole depth is about $4\frac{1}{2}$ inches (being much

the same as that represented in the preceding

Fig. 24.

Fig. 25.

figure), which has been laid down on some parts of the London and Birmingham railway.

Fig. 25. is a section showing rail, chair, and mode of keying the rail.

Fig. 26. is a ground plan.

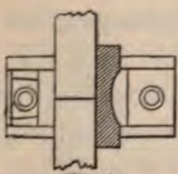


Fig. 26.

These rails are secured by oak keys or wedges. One side of the chair is bevelled vertically, against which the wedge acts, pressing down the upper side of the base of the rail, and forcing it against the opposite side of the chair.

Fig. 27. is the section of a 75 lbs. rail, which was laid down on the Edinburgh and Glasgow railway, showing the form of chair, and mode of keying.

Fig. 27.

The inner side of the chair being curved, admits of ample space for the key to wedge the rail firmly.

Fig. 28. is a section of the rail and chair which

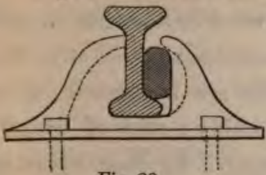


Fig. 28.

is now laying down on the North British railway, about 70 lbs. per yard, in 12 and 16 feet lengths. The top and base are different sections, probably adopted with a view of saving in the weight, but presenting no corresponding advantages. The keys or wedges are made of oak, and are small in size.

The preceding figures will give a tolerable idea of the different forms of rails which have been adopted on railways when supported on equidistant bearings. It may be easily seen, that while choosing a section of rail to have sufficient rigidity or strength for the weight passing over it, the object sought after, is to adopt the most economical mode of construction. It seems generally agreed, that the bearing surface for the wheels to run upon, without being too heavy, or so narrow as in an additional degree to wear the wheels, should be about $2\frac{1}{2}$ inches; and hence this size of a head is generally adopted for public railways. Although, both theoretically and practically, it has been assumed, by Messrs. N. Wood, Barlow, and E. Wood, that the strongest form of rail is that of which, with sufficient depth for rigidity, the base does not

contain too great a quantity of material,—and though Mr. Barlow has given a formula for calculating the section of greatest strength,—still the great object that the public are interested in, is the best form of rail for safety; and of which, while it has sufficient strength to bear upon it heavy loads in motion, the bearers should not be too far apart, to increase in the least degree the amount of either vertical or lateral deflection. When a rail possesses these advantages, its exact shape on mathematical principles is of less importance than its convenience of being easily fixed, and quickly shifted. Hence, while the single parallel rail is decreasing in practical application, the double one, from its convenience, is progressively extending. A knowledge of these facts is essentially necessary for every one engaged or connected with railways, whether he be a director or shareholder, whether an engineer or manager. With all the knowledge yet acquired, there is ample evidence of the uncertainty which still hangs around the subject; and the great expense it has already cost some of the older companies in making alterations, shows that experience to them has been dearly bought. For example, it has been shown that the Liverpool and Manchester Railway Company has had several

times to alter the rails on that line; to increase the weight from 35 lbs., the weight of the original rail, to 50 lbs., 65 lbs., and 75 lbs. per yard, successively; while the London and Birmingham Railway Company, notwithstanding the advantages derived from Mr. Barlow's able report, was obliged to reduce the width of the bearings or supports from 5 feet to 3 feet 9 inches, and to increase the weight of the rails from 64 lbs. to 75 lbs. On other railways equally expensive alterations have been made. There is every probability, therefore, that, so long as that plan of railway construction continues, whatever may be the first cost to railway companies, a still greater weight must be given to the rails, and a still farther reduction of the width of the bearers must take place, in order to adapt the stability to increased rapidity of traction.

Having given a general description of the sections of rails supported on props placed equidistant, I shall now proceed to notice the manner in which the rails are supported and fixed in their respective places. It may be observed that the rails have gradually been increased in strength since steam power was introduced; the bars are usually made in 12, 15, and 16 feet lengths, with square or butt ends, and are laid end to end, the earlier complex contrivances to secure the joints being all

dispensed with, and the half-lap joints (*fig.* 12.) now rarely used. About $\frac{1}{16}$ of an inch, at least, should be left between the ends for expansion; for it has been ascertained that a bar of 15 feet in length will expand about $\frac{1}{11}$ of an inch at 75° F. Some have, indeed, proposed to place a small piece of wood between the ends of rails, as the different expanding properties of wood and iron would fill the space, the wood expanding as the iron contracts: but such a plan is liable to objection from the wood being likely to be shaken out, and the space being left vacant. There is no part of railway construction that requires more accuracy of fitting than the joints: the squareness of the ends, and the space allowed for expansion, cannot be too carefully regulated. Instead of that, how often are seen spaces at the joints of different widths, and the ends of the bars in juxtaposition, without parallelism and uniformity of level; thus increasing the amount of friction, adding to the jolting and rocking motion, and to the risk of the wheels of carriages being thrown off the rails.

SETTING STONE BLOCKS AT INTERVALS.

Stone blocks imbedded in the ballasting were for a long time the chief method adopted for

supporting the iron rails, and they are used on some railways almost throughout the line. On others, the practice has been to use both stone blocks and wooden sleepers, the rule being to place the stone blocks on solid ground and rock cuttings, and the wood sleepers on embankments, and always on the latter till the ground was properly consolidated; and, in some cases, the sleepers not being deemed as the permanent way, they have been replaced by stone blocks. This rule, however, has been greatly departed from; and the adoption of blocks or wood sleepers has been chiefly regulated by the locality or convenience. Mr. N. Wood gives it as his opinion, that when stone blocks can be had at a moderate cost, they are decidedly the best support for the rails. Stone blocks, no doubt, present more firmness, and a more unyielding resistance, than wood sleepers; but as the motion of carriages on the latter is more agreeable, possessing greater smoothness, they are coming into more general use. Formerly, square blocks of wood were made use of, as on part of the Stockton and Darlington railway; but this is now unusual; and, when blocks are laid down, they are made of granite, whinstone, or other hard stone. They commonly consist of a flat stone, two feet square, by one foot

deep. The stone placed at the joinings of the rail usually contains five cubic feet, and the intermediate ones four cubic feet. The distances the stones are placed apart are regulated by the views of the engineer; and, as has been shown, opinion differs on this point, some preferring a lighter rail with a short bearing, others a heavier one with a broad bearing. Experience has however shown, that whatever may be the form and strength of the rail, blocks placed beyond 4 feet (centres) apart, are unsuitable for steam power; and that a less distance is preferable. On some lines the blocks, from centre to centre, are three feet apart, as on the Leeds and Selby, Manchester and Leeds, York and North Midland; on others, 3 feet 9 inches (centres), as on the London and Birmingham, Grand Junction, and London and Brighton; and on others, 4 feet (centres), as on the London and South Western, Manchester and Birmingham, Edinburgh and Glasgow, &c. Stone blocks are sometimes placed diagonally opposite each other, and sometimes at right angles to the line of road. *Fig.* 29. is a ground plan, showing the modes of placing the stone blocks *a b*, and transverse sleepers *c*. It has been considered an advantage to lay them diagonally, instead of square, as steadying the rails, and because that access can be had

to all sides of the block, should it be displaced,

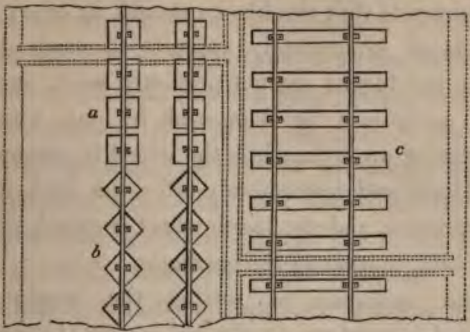


Fig. 29.

and also as affording more lateral resistance. On the London and Birmingham railway, stone blocks are almost entirely used, and they are placed diagonally; and on the Edinburgh and Glasgow, and other lines, they are placed at right angles, which admits of the chairs being placed closer together, and gives more stability.

As the want of parallelism in the blocks is a great defect in railway construction, as also the want of uniformity of level, the proper setting of them becomes most important; otherwise, as the blocks are isolated from each other, and liable to sink, and so require constant packing under them, the rails may be thrown out of gauge, and prove a fruitful source of accidents. Too much care cannot therefore be taken in having the

blocks placed on a solid bed. Mr. Barlow strongly recommends that the blocks should in every case be placed immediately opposite to each other: when the blocks are not perfectly solid, one rail may sometimes be depressed by one wheel a quarter of an inch, while the wheel is perhaps on the block, and immediately after the high wheel is depressed, and the lower wheel is raised, giving a rocking motion to the carriages.

The operation of setting the blocks was effected, according to the old system, by mallets and shovels, beating them till they came to the proper level; but it is now usually done with a portable lever, about twenty feet long, (a plan introduced by Mr. George Stephenson,) by lifting up the block by the short end, about a foot high, and by repeatedly letting it fall upon the coating of the road in the intended seat, and throwing at the same time gravel or fine sand under it, at each descent, to form a solid bed for it: then it is set to the proper level, both longitudinally and transversely, by squares and sights. The distances apart of the blocks being determined, the whole line of road is thus laid with blocks to suit the general inclination. They ought not to be moved when properly seated.

The necessity of setting the blocks contermi-

nously at precise levels must be apparent, when it is considered that even a $\frac{1}{4}$ of an inch in 3 feet is equal to 1 inch in 12 feet, or to an incline rising 1 foot in 144 feet. It is found, indeed, that by a slight difference of level at the ends of the rails, the carriage will pass without touching a portion of the rail; while the least deviation from the straight line, by the rubbing of the flanch of the wheel, will increase the force of traction.

When a railway is therefore constructed for rapid speed, it must be obvious the rails cannot be too carefully laid, as any deviation from the level may throw the carriage for the moment off the four wheels, and it may then be supported even by two; and thus the sudden lurching may produce such lateral blows as to break the chairs from their seats; while the deflection of the rail, as has been noticed, has the effect of making the carriages as it were constantly ascending an inclined plane, although the line of way is a level. That accidents should arise from causes of this kind, often unsuspected, there admits of little doubt, and shows how much depends on the accuracy of workmanship in railway formation.

WOOD SLEEPERS.

Much that has been said with respect to the proper foundation and fixing of stone blocks upon the ballasting, applies to wooden sleepers. The latter have, however, the advantage, that they are made to reach from side to side of a line of rails; so that the two rails are attached to the same sleeper: the rails are thus not so liable to lose their parallelism, or be thrown out of gauge, even should one end of the sleeper sink a little lower than the other, as might happen with blocks supporting rails which had no connection. This is an important fact, which does not appear to have received sufficient consideration.

Transverse or cross sleepers of wood are generally made of larch, fir, or oak; and for a railway where the space between the rails is 4 feet $8\frac{1}{2}$ inches, they are made from 7 feet 6 inches to 10 feet long, with a scantling of from 8 to 12 inches broad, and 5 to 8 inches deep; but 10 feet long, by 12 inches broad, and 5 or 6 inches thick, has been considered not too large a proportion for a 3-feet bearing. They consist usually of half trunks of trees of a small size, and of which the flat side should be laid undermost: a larger sleeper is always placed under the joinings

of the rails. The bed for the sleeper is usually the dry ballasting of the railway, the broken stones being levelled quite smooth before the sleeper is laid in its place. It was till lately the practice to kyanise* the wood sleepers; but this has been greatly superseded by the newer inventions, formerly alluded to, of Mr. Payne, for abstracting the juices and air from timber, and those of Sir J. Burnett. In many instances, however, sleepers of well-seasoned larch are laid without any preparation. The size of the transverse sleepers on the London and Birmingham line is 7 feet long, with a scantling 9 inches by 5 inches; on the London and South Western, cross sleepers throughout 9 feet long, scantling 10 by 4½ inches; Edinburgh and Glasgow, 9 feet long, scantling 10 by 4½; Manchester and Birmingham, 9 feet; Manchester and Leeds, 9 feet, scantling 11 by 5; Midland Counties, 9 feet, scantling 10 by 5; North Eastern, 9 feet, scantling 10 by 6; North British, 8 feet 6, scantling 9 or 10 by 4½ or 5.

Railways formed entirely on cross sleepers are much more common now than formerly, both in this country and abroad. Several lines indeed, which were formerly laid with stone blocks, have been relaid with wooden sleepers. The Belgian

* *Kyanise*, to prepare timber with Mr. Kyan's patent solution.

railways are entirely laid on wood. In this country, on some lines, transverse wood sleepers have been laid down throughout the line, as on the London and South Western, the North Eastern, and others; and several of the lines now forming, are being laid entirely on cross sleepers, as the North British, and others.

There still, however, hangs over this point of railway formation considerable uncertainty; for although on one line stone blocks may be entirely removed, and timber substituted, on another the reverse of this has been the case, from the decay of the wood. Cross sleepers too, unless they have sufficient scantling, and are considerably wider than the gauge of the rails, are liable to be displaced by the least sinking of the ground; and as there is nothing to prevent the sleepers from rising but the ballasting, this plan cannot be deemed perfect. It has, however, become extended, from its cheapness and facility of execution, and diminution of rigidity.

The London and Greenwich railway affords a good example of the smoothness attending the use of timber bearings. Had the rails been laid on stone blocks upon the viaducts, it must have much increased the harshness of motion.

Some attempts have been made, both in this

country and in America, to introduce the use of stone blocks in the same manner as transverse wood sleepers are laid; proceeding on the idea, previously noticed, that their parallelism was less likely to be disturbed, or the rail thrown out of gauge, from any inequality or yielding of a block, than when laid in the common manner. The Dublin and Kingston railway was laid on thorough-going blocks of granite of this kind, 6 feet long, 2 feet wide, and 1 foot thick: these were laid across the way, at 15 feet apart, and intermediate single blocks of the ordinary kind were placed between them, at the distance of 3 feet. Probably, from the difficulty found in adjusting properly the bed for such heavy blocks, and from the vibration and jolting of heavy trains on a hard bed, and breaking of the long blocks, the plan turned out a failure; and the stone blocks have been entirely taken up, and timber substituted. Sometimes transverse sleepers made of cast iron have been used in place of timber. Cast-iron bed-plates have also been proposed, instead of stone blocks; but it is considered iron has too much rigidity for these purposes.

In the United States, transverse stone blocks were tried at the Boston and Lowell railway: the blocks were made of granite, 6 feet in length,

and 18 inches square, and placed at 3 feet apart, centre to centre, each block supporting both rails, the gauge being 4 feet $8\frac{1}{2}$ inches. This plan was found, however, to produce too rigid a road. In some instances, to attain a greater connection between the blocks when placed separately, iron tie or connecting rods have been used at curves.

SEATING THE CHAIRS UPON THE BLOCKS.

When the blocks and sleepers have been placed along the line of a road, the next thing is to set the chairs, or pedestals, which are to support and fix the rails. These are usually made of cast iron, for convenience, on account of the irregularity of shape. Malleable iron is, however, much stronger; but though a patent has been obtained for making them of it, they have not been yet introduced. As great a variety of forms has been proposed for chairs, as for rails, because the former must be adapted to the latter. The chair generally stands vertically, having an open socket or groove to receive the rail, the base of which being, when set in the chair, about an inch clear of the block or sleeper. The distances the chairs are placed apart, are of course regulated by those of the blocks: they are fixed to the blocks in the following manner:

Holes are drilled in the stones, from $1\frac{1}{2}$ to 2 inches in diameter, into which plugs of oak, or tree-nails, are driven; and the chair being placed on its seat, and accurately levelled, iron pins or spikes, with heads, are driven through the holes in the base of the chair, into the wooden plugs, which fixes the chair fast to the block. When chairs are to be fastened to wooden sleepers, the ends of the latter are cut to the proper level, and the chairs are nailed down with strong spikes. There are usually two perforations in the intermediate chairs, as on the North British railway; but on some railways the chairs have three, as on the London and Brighton; two on one side, and one on the other. The holes are sometimes placed diagonally, and generally so in the joint-chairs.

The weight of the chair is regulated by the size and strength of the rail, and both are made much heavier than formerly. The 76 lbs. rail on the London and Brighton railway has a chair at the joinings $10\frac{1}{4}$ inches wide by 5 inches high, and the intermediate chairs are $10\frac{1}{4}$ by $4\frac{3}{4}$ inches. The chairs on the North British railway are 10 inches wide, 5 inches high, 5 inches broad, and the intermediate ones 10 inches wide, 5 inches high, and 4 inches broad.

The weights of the heavy chairs on the London and Birmingham railway are, joint chairs 31 lbs., and intermediate ones $26\frac{1}{2}$ lbs.

Pieces of felt, when stone blocks are made use of, are now very commonly interposed between the iron chair and the block. When the chair is firmly pressed down by the pins, the felt forms a bed for it, giving it a firmer seat, and likewise diminishing the jolting and concussions of the carriage wheels, and the rigidity of motion upon the hard stone block. It is found, however, that in a few years the good effect is nearly lost, from the constant action of heavy loads on the rails, and that the chair bears hard upon the block.

The chairs upon most of the principal lines where stone blocks are used, such as the London and Birmingham, Edinburgh and Glasgow, &c., have felt placed under them.

WEDGING OR KEYING THE RAILS TO THE CHAIRS.

When the iron rails have been laid into the open sockets of the chairs, the next operation to be performed is called keying the rails, which is done by means of wedges called keys, one of which is driven hard into a small vacant space left to receive it, between each chair and the outer side of the

rail, which is intended to firmly bind and secure the rail in its seat. Various sorts of keys have been prepared: they are most commonly made of oak or elm, both compressed and uncompressed, and also prepared by the patent process. Both solid and latterly hollow iron keys have been tried.

Fig. 30. is a sectional end-view of Mr. Barlow's patent hollow iron key, applied to wedge a double parallel rail. This form of key has been very favourably thought of.

Fig. 30.

As on the proper keying of the rail much of the stability depends, too much care and attention cannot be bestowed upon the subject: hence the contrivances are numerous. The chief object of the key is to keep the rail firmly down in the chair, and at the same time not to prevent the longitudinal expansion of the rail. The kind of key understood to answer best, depends much on practical experience. The general use of wooden keys for wedging rails, arises from the greater facility they afford for their being tightened and replaced; but to attain this object, the wedges should be of ample size. Nothing demonstrates more the imperfections attending the construction of rail-

ways, where chairs and keys are used, than the constant watching the line of way requires, for tightening the keys. *Figs.* 25, 26, 27, 28. illustrate the manner of fixing the rails with wood keys.

RAILWAYS ON CONTINUOUS BEARINGS.

Having now traced the progress of railways constructed on the plan first introduced by the late Mr. Jessop, in 1789, to the present time, it may be observed, that the laying the rails on alternate props or supports over the entire length of the road, whether they were made of wood or stone, has been the plan in general use, and seemingly has been considered by engineers to be the best. It is at first view extremely difficult to account for this partiality; for after the introduction of steam power on railways, difficulties presented themselves in the construction of this form of railway, which had not been foreseen. Instead, however, of attempting the introduction of a new principle of laying the rails, large sums have been expended by the older companies in altering the form of rails first laid down. It is indeed amusing to observe how much has been written on vertical and lateral deflection, on the strength

and rigidity of iron, and on railway chairs and keys; when it seemingly required but little ingenuity to devise a scheme, where the obvious deflections of a bar suspended on two fulcrums, as a bridge, could be got the better of, by placing the bar on a solid foundation; while greater safety and stability would be attained, and complicated contrivances to fix the bar become unnecessary.

That any diminution of vertical deflection, by placing the bars on a solid base, is important, must be apparent to all, when it is considered that a heavy load depressed, must be like ascending an inclined plane on the rail, the height of which is equal to the central deflection. It was assumed, however, when the Great Western Railway was under consideration by the parliamentary committee, that as much power was gained in the descent as was lost in the ascent, the odds being made even; and thus the deflection would be no impediment; but Mr. Barlow has shown that this assumption is erroneous, both in theory and practice, and that in fact the gain from the descent is so exceedingly small, in such short planes, that it may be wholly rejected; so that in a plane supposed perfectly horizontal, the retardation or additional resistance to the carriages, caused by the deflection of the bar, will be equivalent to

the carriage being carried up a plane of half the whole length on a slope.

Solidity of the base of rails, upon which heavy carriages are to run, being, as a preliminary point, so obviously and essentially requisite, the only wonder is how it can be discussed at all. Yet we find engineers stating, that between rails firmly fixed to solid longitudinal bearers, and rails suspended in the common way between two points, not much difference of deflection exists. The fallacy of the statement is, however, so apparent, that it is hardly deserving of notice, were it not that such assertions have the dangerous effect of misleading the judgment of impartial inquirers. It may be therefore laid down as the rule of common sense, that the more firmly a rail can be laid continuously on a solid bed, the less vertical deflection or bending it will have; and unless iron bars, when suspended, can be made equal in strength, and to bear the same weight, *ceteris paribus*, the first plan must have most stability, not only in bearing the vertical strain, but also the lateral one; for surely it requires no argument to show that an iron bar laid upon a series of points, or fulcra, must be much easier bent vertically and laterally by the heavy blows or jolts of a carriage, than when the same bar is made to form a part of the solid

roadway on which the carriage runs. However much, therefore, some may consider as questionable the supposed advantages of rails laid on continuous bearings, the defect, if any, cannot appertain to the principle, which, the more it is examined, will carry the more conviction with it; but it must appertain to the details of the construction. For instance, on some railways with continuous bearings, the rails are fastened into chairs, and rest upon intermediate saddles.

When the iron rails are laid down, however, in this manner, the tension and elasticity of the bar—bound at intervals, like the strings upon the bridge of a violin—are not removed; in fact, there is no difference in the principle from rails laid upon cross sleepers: and it may fairly be admitted, that rails so laid upon longitudinal sleepers are inferior, in many respects, which could be pointed out, to rails laid upon transverse sleepers.

It should therefore be kept closely in view, that when a railway is said to be laid on continuous bearings, it is meant that the *base* of the rails rests *entirely* upon the solid timber. It has been shown that the old tram-road, first used in this country, was nothing but continuous logs of wood, with cross ties, adapted to the width of the carriage-wheels. When this system was intro-

duced in America, where, from convenience, it has been extensively adopted, it was farther improved, rendering it more adapted for steam power; and on the Continent some railways have been similarly constructed. The introduction of this form of railway in America has been attributed to the abundance of timber, an advantage which this country does not possess: but the question which the public are most interested in, is not, where the material comes from, or even the cost of it, but what is really the best plan.

One of the first engineers who has made the attempt to introduce into this country a railway on the American construction, but with iron edge-rails, was Mr. I. K. Brunel, who did so on the Great Western railway; and it required both courage and ability to attempt an entire alteration in the railway system which had for several years previously worked so well; and perhaps few engineers would have attempted the bold experiment at once, which he did, of constructing so many miles of a railway differing so much in detail from the method of laying the rails previously in general use. The principle is therefore deserving of most careful consideration; for if it ultimately turn out, by successive future improvements, as successful as it has already proved,

this form of continuous railway may supersede the common mode of construction, and perhaps lead to the remodelling of many railways now in existence.

It is generally understood that the objects which Mr. Brunel sought to attain, in proposing a railway on the American construction in this country, was, that while it could be made at no more expense than on the common method, it might be cheaper maintained, and much more agreeable to travel over, as there would be less concussion and jolting, and a smooth, equal, and elastic road, without any undue yielding; in fact, that though there would be a less unyielding surface to pass over, than on rails laid on stone blocks, there would be sufficient firmness for safety, and less liability to the parallelism of the rails being disturbed, while both vertical and lateral deflection of the rails would be diminished.

That he has not been disappointed in his surmises, in many of the points, can be disputed by few: that his views were not fully realised in the construction of this railway, arises from the inexperience which surrounds so many points of an infant science. It may be objected, that a fair comparison cannot be drawn between the Great Western, from its great breadth, and common

railways: but there are other lines in this country, of the common gauge, laid with continuous bearings, by which a comparison can be made.

Before proceeding to describe the manner of laying the sleepers on the Great Western railway, it is necessary to notice the form of the iron rail which Mr. Brunel adopted, as it differs entirely from those previously described, requiring neither cast-iron chairs nor wedges. It is the more necessary to understand the construction of the rail, as on the stability of the rail, and its proper adaption to the road, much of the safety of carriages running at high velocities will depend.

Fig. 31. is the form of rail which was first laid down on the Great Western. It consisted of a hollow malleable iron bar, made in 15-feet lengths, having two broad flanches perforated at intervals of 16 inches, for admitting the screw-bolts for fixing the rail to the timbers; the outer bolt having the head raised above the flanch, and the head of the inner bolt being counter-sunk or flush with the iron: the original rails were only 44 lbs. to the yard, and were 1¼ inch high. This form of rail is termed the bridge or hog-troughed rail.

Fig. 31.

LONGITUDINAL SLEEPERS, OR BEARINGS, ON THE GREAT WESTERN.

As the plan which Mr. Brunel has adopted for the sleepers or frame-work of the Great Western, as now arranged, does not differ greatly from the American railways, and others which have been laid in this country, it will easily be understood. It may, however, be instructive to describe the first plan of forming the line of way laid down from London to Maidenhead, 22½ miles; but which is now in the course of being entirely altered. On this part of the line Mr. Brunel made use of piles driven at intervals, in order to give greater security to the continuous timbers, so that they might not rise up or go down; but these piles have been found to be unnecessary, and so to add much to the cost of the railway, without any corresponding advantages: they are therefore now being entirely removed, and longitudinal timbers of greater scantling substituted.

Fig. 32. is a transverse section of a pile driven into an embankment.

In forming the railway, when the road was constructed, beech piles, 10 inches in diameter,

and 10 to 14 feet long, at intervals of 15 feet, placed rather closer to the outer than to the inner rails, one pile between each pair of rails, were driven into the solid ground, in cuttings about 8 or 10 feet from the surface level, and in the embankments through the laid earth several feet into the natural strata. The vast labour and expense attending driving so many piles may easily be surmised.

Fig. 32.

The head of the pile was made to stand about flush with the ballasting, and a groove of $1\frac{1}{2}$ inch was cut out on the side, near the top of each pile, into which the cross-ties or transoms of American timber were let, which connected the piles together.

Every alternate pair of piles was placed between two cross-ties, and the intermediate piles had one cross-tie: the double cross-ties were 13 inches below the line of the rails, and the single one 9 inches. On the transoms, and framed with them, were laid the longitudinal timbers which support the rails: they were of American pine, 15 inches

wide by 7 inches deep, each pair being laid at 7 feet 2 inches centres: they were made to rest upon a piece of wood inserted between the double cross-ties, and they were sunk a little into the intermediate tie, which was made a little deeper than the double one: they were secured together by strong screw-bolts and nuts, with the heads countersunk, as shown in *fig.* 31., into the upper surface.

There were screw-bolts at every point of intersection with the transverse ties or timbers, so as to firmly bolt the whole together, and the latter with the piles: the timbers were laid carefully to the plane of the line of way, and perfectly level transversely, excepting at curves, where the inclinations of the cross timber was adapted to the radius. Both cross and longitudinal timbers were packed with sand and gravel, which was beat under them, so as to form a solid and compact bed; and the beating was even continued till the timber was strained, as Mr. Brunel's object appeared to have been to throw up a vertical strain against the bars of the rail, to counteract the effect of the downward weight, and to rely on the retaining power of the piles to hold down the timbers.

When the longitudinal timbers were fixed, the surface was smoothed to a uniform level, and

upon this a planking of American elm, $1\frac{1}{2}$ inch thick, and 8 inches broad, was laid, bedded with tar, having a slight inclination inwards, the angle of the slope being 1 inch in 20 inches. When the planking had been firmly nailed down, and the heads of the nails sunk flush, the iron rails were then fastened upon the thin planking, (pieces of felt having been placed between them,) by means of stout screw-bolts, with a deep-threaded screw, passing through the perforations made in the flanches of the 44 lbs. rails, into the solid wood. The outside screws had square heads, and the inside screws had the heads countersunk: a heavy roller was passed over the rails, to aid the firmer screwing up of the bolts. For the preservation of the timber, the whole of it was previously kyanised, and the iron-work laid with tar. It has been estimated that the timber used in each mile of this railway was 420 loads of pine, and 40 loads of hard wood, and that also 6 tons of iron bolts, and 30,000 wood screws, were used.

Such is a description of this most elaborate work, which it is useful to preserve. It affords another instance, of the many, of the truth of the adage, that the best laid schemes too often prove fallacious. That this plan has not altogether proved successful, is no more than is every day

seen to occur, although the results of the first trials made seemed to have been satisfactory. It was soon discovered, as already mentioned, that the advantages to be derived from driving the piles, notwithstanding the extra expense, were but trifling. They were therefore discontinued on the line beyond Maidenhead, and longitudinal timbers and cross sleepers only employed, the latter being laid at closer intervals, and the scantling of the timber of both reduced, probably with the view of lessening the expense. The radical defect of this railway was soon, however, discovered to be, that the scantling of the timber and the rails were too light for heavy loads passing with rapidity; and, in consequence of accidents on the line, the whole timbers of the railway between Maidenhead and London are now in progress of being removed, and timbers of much heavier scantling substituted, upon the same plan as that upon which the southern portion of the line had been executed, and which is simple in construction.

Fig. 33. is a section and elevation on a small scale of the longitudinal timbers as now being laid down at the Slough station, and as existing in the western portion of the railway. They are half-logs of wood, with a scantling of 15 inches by 9 inches

or more, and the cross sleepers are 5 inches by 8 inches. The cross sleepers are placed at intervals

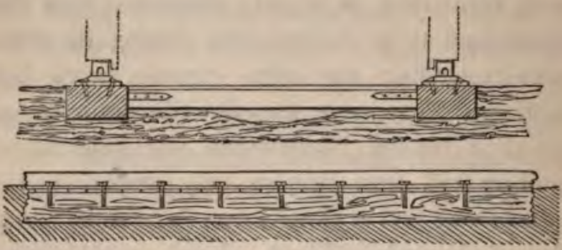


Fig. 33.

of 9 or 10 feet, and are firmly secured to the longitudinal logs by means of bolts and iron straps, forming a strong frame. The iron rails have been increased in strength and size from 44 lbs. (the original) and 55 to 62 lbs. (those laid down on the parts of the line last executed), to 70 lbs. per yard.

On the first 22½ miles, where the lightest rails were used, the head of the inner screw-bolt was countersunk, as has been described, flush with the iron, to avoid coming in contact with the flanch of the wheel. Beyond this distance, on the remainder of the line, the rails being increased in height, a nut was used for the bolt, both inside and outside of the rail, for convenience of tightening the screws. This plan, however, in reality gave no more depth to the flanch of the wheel,

as the head of the screw was nearly equivalent to the increased height of the rail. It appears to me that the first plan was the most correct one; for, by having the head of the screw sunk flush with the rail, no more height was given to the rail than was required properly to clear the flanch. Besides, if the first height was too little, it might have been increased without altering the plan of fixing; for it will not be disputed that the lower the rail can be kept down, the more stability it must have; whereas the carriage-wheels being now raised some inches clear of the base, there is the certainty of more oscillation or rocking of the carriages taking place.

Fig. 34. represents a section on a large scale, of the rail laid down upon the western portion of the railway, in which the heads of both the screws are raised above the base of the rail.

Fig. 34.

In the new rails, laying down in the re-construction of the permanent rail between Maidenhead and London, the height of the rail has been increased from $1\frac{1}{4}$ the original rail to $2\frac{1}{2}$ inches. The width of the bearing surface for the wheel or the top of the rail is much the same as some of

those in use, being about $2\frac{1}{2}$ inches. It has, however, been stated, that it is intended that in the new rails laying down, the heads of the screws are to be sunk flush. Instead of being, as the first rails were, laid with a layer of felt under them upon the top of the $1\frac{1}{2}$ inch planking of American elm,—thus affording a solid and compact bed,—the planking has been discontinued in placing the new rails, and the rails are merely laid upon pieces of prepared hard wood, about half an inch thick, and eight inches broad, which are nailed upon the longitudinal timbers, the felt also being dispensed with. It is difficult to perceive any advantage that this plan has over the former one: on the contrary, the friction of heavy loads may have the tendency to loosen these small pieces of timber. Were the rails simply laid down on the solid logs, on a bed of felt, as on the Croydon railway, the stability would be very much greater; or, at all events, the first plan of using a plank, about two or three inches in thickness, nailed to the longitudinal timbers on which the rails might be fixed, must afford a more solid bed than the plan now adopting.

I have been thus particular in describing the plan of the Great Western railway, as the success of the experiment must be interesting to the railway

world. In my opinion, Mr. Brunel has not yet done justice to his plan, by keeping the scantling of the timber the size he does. Even that which is now laying down is much too light for heavy trains at great velocity—which time will show; and he cannot expect the success that his plan deserves, unless a firmer base is given to the rails, which can only be done by increasing the scantling of the timber, and placing the transoms, or cross-ties, at closer intervals; the adoption of which would afford all the advantages which can be obtained from a firm and unyielding base, and at the same time combine smoothness with stability.

The plan of rails adopted on the Great Western line has, as yet, not been much extended to other railways. The Irish Commissioners have introduced this plan on the Ulster railway, between Belfast and Portadown. The rails laid down are of the bridge form, and are of from 15 to 20 feet lengths, and 53 lbs. weight per yard. They are not bedded on felt, but are screwed to the timber with $\frac{5}{8}$ screws, 5 inches long, inserted at intervals of 16 inches. The longitudinal timbers have a cross section of 12 inches by 6 inches, having a lateral inclination of $\frac{1}{16}$ of an inch. The transoms, or cross-ties, are placed at intervals of from

10 to 15 feet, under the longitudinal timbers. On some other railways, the plan of the Great Western has likewise been adopted on small portions of the line.

CONTINUOUS BEARINGS ON CROYDON RAILWAY.

Another plan of iron rails laid on longitudinal timbers has been most successfully tried on the London and Croydon and other lines. On the New Orleans railway a similar form of rail has been adopted; and on some of the American railways the same form of rail has been used, fixed differently, namely, with clamps, driven into the longitudinal wooden sills.

Fig. 35. is a section of the broad-based T rail, made in 15-feet lengths, which has been used on the London and Croydon railway. The rails are laid on longitudinal timbers, with a scantling from 10 to 14 inches broad, by 5 to 7 inches thick.

Fig. 35.

These are fixed to cross sleepers of wood 9 feet in length, with a scantling of 9 inches by 5 inches, and secured by half-inch spikes, 9 inches

in length. A layer of felt is placed between the iron rail and the longitudinal sleeper; and the former is firmly screwed down by half-inch screws, $4\frac{5}{8}$ inches long, and bolts, with a head 1 inch in diameter, placed at intervals in pairs, 19 inches apart. At the joints, four screws are put in, near each other. The heads of the screws are countersunk in the inner flanch, and are 4 inches long. From the low vertical section of this rail when compared with those placed on chairs; and from the base resting on continuous wooden sills, it possesses both strength and stability. This plan, of laying the rails upon the solid timber, is an excellent one; and this railway affords, perhaps, the best example in the United Kingdom of a smooth and elastic rail, with absence of noise and sufficient stability, as the rails are so bound together that they cannot easily get out of gauge; while the wear and tear in working must be diminished, and corresponding safety increased.

The form of rail here adopted, though remarkably free from friction, and affording ample room for the flanch of the wheels, does not seem to present any superiority to the bridge form on the Great Western, were the latter placed in a similar manner on the solid timber, although some may fairly consider that the squareness of the

flanch of the wheel, on the Great Western, to suit the bridge rail, is no advantage; but, on the contrary, increases the amount of friction.

A part of the Birmingham and Gloucester railway has been laid on longitudinal sleepers of American pine, in various lengths, with a scantling of 13 by 6 inches, connected by ties, 7 feet 2 inches long, with a scantling of 7 by 3½ inches, being half-round logs; the chairs being secured by strong screwed bolts.

Fig. 36. is the section on a large scale of what is called a shallow parallel rail, laid down on part of this line, at 56 lbs. weight per yard.

Fig. 36.

Part of the Manchester and Bolton railway is likewise laid on continuous bearings of wood, or half-baulks, set a little diagonally, with cross sleepers beneath the longitudinal timbers, as on the preceding line, with rails of the same form. On the Dublin and Kingston, and other railways, continuous bearings of wood have in portions been laid, but with a flat-based parallel rail, the rails, as previously noticed, being set in chairs.

Iron edge-rails have also been tried in this country, on continuous stone blocks, instead of

timber. On the Bolton and Preston railway, on which the works are laid in this manner, they are 5 feet in length, and 2 feet in width, and the blocks are imbedded in brick sleepers. On part of the Leeds and Selby railway, where a continuous line of stone blocks is placed under each rail, they are 3 feet in length, 1 foot deep, and 16 inches wide: the four lines are kept together by means of iron ties, running from one side to the other. This plan of railway, when the stones have a solid foundation, must be a very durable mode of construction: but where continuous stone blocks have been used, the harshness and rigidity have been found too great for heavy loads passing with rapidity, the impulse being much more severely felt both by the carriages and machinery: hence this plan has not been extended in this country. It is more than probable, however, that iron rails, laid solid upon continuous bearings, will ultimately be extensively adopted; and that, from their many advantages, the public opinion will be extended in their favour. There can be no doubt that the smoothness and less noise of the carriage evince a more easy working, and less friction and jolting of the machinery. A fair comparison can be made between the London and Croydon and any line laid upon other bearings.

There does not appear on the Great Western, or other lines laid with continuous bearings, to be much, if any, diminution of the oscillating or rocking motions of the carriages. On the Great Western, this may or may not be influenced by the gauge; but, at all events, there is a freedom of that jolting and harsh grating noise so apparent on some lines. The great point, however, even more important than the smoothness of motion, is preventing the rails being thrown out of gauge; and railways constructed like the Croydon, with cross sleepers or transoms at close intervals, must afford a very effective security. However, even on bearings thus laid, much will depend upon the solidity of the railway, and the ballasting and packing, although it must be self-obvious, that when the longitudinal timbers are framed together, it affords more certainty of stability than when rails are placed on separate blocks, and sleepers easily influenced by concussion, and even by the weather.

FLANCH OF THE WHEEL.

Having described the different forms of iron rails now used on railways, it may be useful here to notice the flanch of the wheel, upon the adaptation of which to the rail depends the diminu-

tion of friction, rapidity of motion, and retention of the carriage on the rails, especially at high speed.

Since cast-iron wheels were introduced for coal waggons, various improvements have been made on them. The first was the mode of case-hardening the rim of the wheels, for which a patent was obtained by Messrs. Loch and Stephenson. Cast-iron wheels were next made with wrought-iron tires. Mr. George Stephenson obtained a patent for a wheel having a cast-iron nave and rim, and hollow iron spokes. Since then, Messrs. Jones of London have obtained a patent for a wheel with wrought-iron spokes and rim, which is getting much into use in London for carriages on common roads, and has been used successfully on railroads. Mr. William Loch obtained a patent, in 1830, for a wheel with wrought-iron spokes and rim. This wheel has been extensively used on railways. Previously to this patent, the wheels of railway carriages were much used with cast-iron rims, hooped with wrought iron; but now wheels are generally formed entirely of wrought iron, except the nave. Cast-iron wheels are, however, now rarely used for carriages, except when drawn by horses; for rapid speed they can never be made use of with safety.

Mr. Loch obtained another patent in October, 1842, for further improvements on wheels of railway carriages.

The flanch of the wheel is that part of it which constitutes one of the most important points connected with railways: and in railways where curves exist, which is the case on almost every railway, the adaptation of the flanch and the cone of the wheels to the form of the rail increases in importance: the flanch is commonly made about one inch deep, slightly bevelled off from the inner side to the outer, in order that, when the wheel is running in a direct line, the edge of the flanch may be kept about an inch clear of the rail, or from coming, if possible, in direct contact with it. To effect this object, the tire of a wheel about 4 inches broad is usually made in a slight degree conical; in a wheel 3½ inches broad, the inclination on the tire is 1 inch in 7; so that the diameter of the whole wheel is greater by 1 inch at the flanch than at the outer edge. By this adaptation, and the slight convexity, the range of contact between the wheel tire and the rail is very much restricted, which necessarily causes its wear. To get the better of this, in a certain degree, it has been the practice with some engineers to give a slight degree of inward inclination to the rails, in order that the

surface on which the wheel acts may be enlarged; although it is obviously apparent, that the greater the extent of surface which comes in contact, the greater must be the friction on the point of inclination of the rails: engineers, however, differ much in opinion.

On the London and Birmingham, the inclination of the rails is stated to be $\frac{3}{8}$ of an inch in 11 inches, or about 1 inch in 29 inches; and on the Great Western, as already noticed, about 1 in 20 inches. On the latter railway the flanch of the wheel has much less bevel than on common railways: this arises from the peculiar form of the rail itself: to adapt the carriage-wheel to it, the edge of the flanch is flat and square instead of being made thick and bevelled.

On one railway, the Eastern Counties, where the carriages have run several times off the rails, occasioning very serious accidents, it has been ascribed to the improper application of wheels with flanches not bevelled, or sufficiently deep, but thin and shallow, of the same form as the Great Western, to rails of entirely a different shape, viz. the common parallel rail. If this is the fact, it must have proceeded from mistake, or ignorance in respect to the proper adaptation of wheels to suit the form of rails; for one can

hardly conceive it possible that carriages with defective flanches would for one instant be permitted to run, endangering the lives of hundreds. Indeed, the official report by the Company, on the recent railway accident, ascribes it "to the defective joint of a rail being caught by the flanch of a wheel of the engine, the flanches not being adapted for the Eastern Counties' railway, and that the engine would not again be used until the flanches had been altered."

In order to attain greater command over the retention of carriages on the rails at high speed, some persons have considered, that were the flanch made deeper, the liability to run off would not be so great, as a broad flanch must retain the wheels better; for the same jolt which would throw them off in the one case, would retain them in the other; and thus half an inch more flanch would prove a great additional security. The deepening, however, of the flanch, as rails are commonly used, would be attended with some practical inconveniences. This, however, is a point of vast importance; but the solution of it can be best attained by experiment. Others have considered, that by increasing the number of carriage-wheels, the risk of running off would be materially lessened. The usual number of wheels is, six

for the engine, and four for the tender and carriages. The Great Western Railway has, however, in general, used six wheels, both for engines and carriages; which, although it may increase the amount of friction-surface, has the obvious advantage, that if an axle breaks, the carriage would still continue on the rails. Mr. R. Benton of Birmingham has a patent for deep-grooved iron rollers, to be placed under the engine-frame or a leading carriage, within and close to the front wheels, upon which the carriage would fall, if the wheel runs off the rail, or were an axle to break on a four-wheeled carriage. Should this plan prove efficient, it might be extended by providing every carriage with rollers, as the expense would be small.

Sir George Cayley suggests, in a letter in the "Mechanics' Magazine," that the front wheels of engines should be provided with three or more grooves, capable of running on the rails, to prevent the engine from being thrown off, in the case of any obstruction which causes the engine to "jump." By this means the engine could be kept in its right course till the train could be stopped. But the suggestions are indeed so numerous on this head, that it is impossible even to notice them. Most of them labour under the disadvantage of want of

experimental application, by which alone can their utility be tested. Amongst other proposals, is one to have double-flanched wheels, at least for the engine; which would have the effect of retaining the wheels on the rails, even were the flanch of the fore wheel raised from it; and by this means the engine would be restrained from leaving the rails.

Some have attributed the liability and frequency of carriages running off the rails, not to the want of depth in the flanch, or even imperfection in the rails, but to the centre of gravity of the engines being too high, which increases the oscillation.

Professor Melson and Mr. G. Heatin of Birmingham ascribe such accidents to the neglect of the accurate balancing of the revolving parts of the machinery, which occasions the violent oscillations, the jerking, and leaping motion on the rails. They have tried a number of experiments on the effects produced from the want of equalisation in the system of rotatory machinery: they propose to counteract the bad effects by counterpoising the weight of cranks and connecting-rods, &c., by means of a contrivance to balance the machinery, and so produce a smooth and equable motion.

CARRIAGE, AXLE, AND BEARINGS.

The axles of carriages is another point connected with railways deserving of much consideration; and consequently many improvements have been made on them in recent years. Comparatively few accidents now happen from breaking of an axle; but when it does occur, the most serious consequences may arise. The axles are always made of scrap or malleable iron, of the best workmanship, and about $3\frac{1}{2}$ inches in thickness; but the engine axles are much stronger than those of the carriages. It is of course well known that the principle of fixing the wheels of railway carriages is the reverse of that of carriages on common roads. In the latter, the wheel revolves on the axle; whereas, in the former, as the wheels are guided by the flanches, and the carriage does not require to turn round, the wheel is securely fixed on it. In the nave of the wheel of railway carriages a square hole is bored out, to get a more perfect fit, and the end of the axle is wedged fast into it. The bearings in which the axle turns are in common waggons placed inside the wheels, when these are outside the frame-work; but, by the improved plan, the bearings are placed

outside the wheels. The latter plan admits of a greater width of the frame-work of the carriage, from being elevated above the wheels. This plan is therefore generally adopted for railway carriages, although it has the effect of making the centre of gravity higher than by the other plan. It presents, however, an advantage over the plan of having the journal or bearing inside of the wheel, that less friction is created, as the journals of wheels 3 feet in diameter, may be reduced from $3\frac{1}{4}$ to $2\frac{1}{4}$ inches; thus the latter will present a much less surface in contact: the journal of the axle is always turned with the utmost accuracy, as the least inequality is productive of serious consequences. The outer end of the journal is swelled out in diameter with a collar to keep the axle, when *in situ*, from moving laterally or outward. A brass bush, in which the axle can turn with facility, is fixed in a cast-iron chair or box, made in two pieces to embrace it, and when so placed they are bolted together. The chair or box is then firmly fixed to the framing of the carriage.

When concave springs are used, which are most common in railway carriages, the centre of the spring rests on the top of the chair, and is fastened to it by the same bolt which fastens the

chair together. Vertical plates of iron, or guides embracing the chair, but allowing action for the spring, are fixed to the side of the framing of the carriage, and work within the projecting part of it. As it is important that the guides should be fixed in such a manner that no working can take place, they are firmly stayed with iron connecting bars and a cross bolt between each stay.

An ingenious contrivance has been provided for lubricating the axle of the carriages, which, from the rapidity of motion, is rendered constantly necessary; a small chamber or box is made directly above the bearing of the axle, having a small hole at the bottom, through which the matter percolates upon the journal when the axles get in the least degree heated. The box is filled with a kind of ointment, about the consistence of butter, made of tallow, palm oil, sulphur, &c., by means of a lid which lifts up, outside the wheels, with a spring to keep it closed during the motion of the carriage. The lubricating matter is commonly made by the railway companies; but several patents have been taken out for different compositions for this purpose.

CARRIAGE-SPRINGS.

From the speed at which carriages on railways now move, and the number of carriages which are necessarily linked together, and the jerks and shocks they are liable to when stopped or put in motion, great strength of frame is not only necessary to prevent their being injured, but such an adaptation of springs as to modify the effect of the concussion, prevent the carriages from striking hardly against each other, and to extend the shock gradually over the whole train; an elastic yielding throughout the train, therefore, becomes necessary. By the plan of connecting the carriages by means of iron bars the whole becomes as one, and hence one blow, or jerk, is felt simultaneously; but as every change of motion must produce a shock throughout the train, and the more violent according to the velocity, the idea presents itself, that the violence of the shock might be prevented by a series of springs. Various ingenious contrivances have accordingly been made for this purpose — most of these improving on the original plan of the carriages of the Liverpool and Manchester Railway, where the necessity of using springs

from the increase of speed became the more apparent. From carriages on railways requiring nearly a straight-forward motion, an arrangement of the springs was obviously wanted to meet the direct tractive force, viz. one class of springs to relieve the body of the carriage from the jolt of the axle, and the other to resist the transmission of direct concussion. As the frames of the carriages on most railways usually project over the wheels to obtain greater width of body, the lowness of the wheels and carriages, and weight of the latter, in a great degree lessen the imperfection of such a plan, and the risk of overturning. The frame of the carriage is usually made to rest on elliptic lapped springs, which are supported upon the iron chair of the axle of the wheel. The springs formerly were often placed above the frame of the carriage, which had the advantage of enabling the platform to be kept lower, but they are now usually placed under the frame. The springs are now made much larger and much less concave, than at one time; and in the most improved carriages the lapped springs are made very long, and nearly quite straight: these do not rest on the chair axle. Grasshopper springs are used on some lines, but are not common. The springs of heavy carriages are necessarily made of great

strength. The plans of carriage springs vary, however, considerably.

The other class of springs used in railway carriages is termed buffers, which are round blocks or discs of metal or wood, projecting from the ends of carriages, commonly covered with cushions; these buffers are fixed on the ends of long iron rods, placed under the carriages in the frame-work, having free motion inwards, and pressing against the end of an elliptic spring when subjected to pressure, or brought in contact with the buffers of the adjoining carriage. As all the buffers in a line of carriages, whatever be the number, are all made to stand directly opposite each other, it obviously follows, that whenever any concussion takes place, as the sudden stopping of a train, the shock, by their elasticity, is much lessened throughout; these springs act equally effectively, whether in pulling or pushing the carriages.

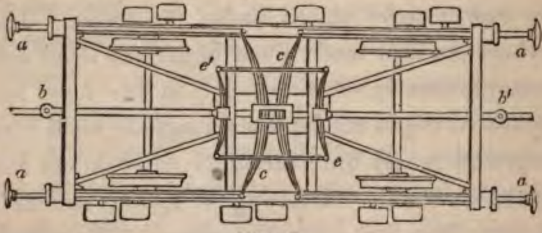


Fig. 37.

Fig. 37. is the ground-plan of a carriage, which

may convey some idea of the action of the buffers: *a a* are the buffers; *c c* the elliptic springs; *b b* is the apparatus for drawing the carriages, with the small springs *e e.* The connection between the carriages usually consists of a jointed bar of iron, which is quickly joined or separated by the removal of a pin, in addition to which spare chains are always used.

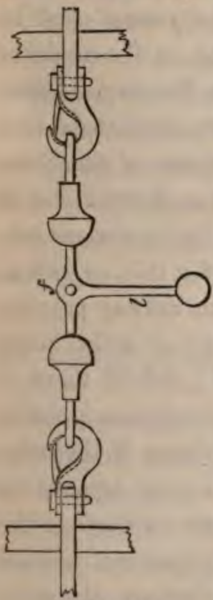


Fig. 38.

Besides this form of spring, various other contrivances have been proposed and in use. Mr. H. Booth obtained a patent in 1836 for a plan of applying buffers, keeping the heads constantly in contact with each other by the pressure of springs acting on them, and by shortening the drag-chain, and fixing the carriages by draw-screws.

Fig. 38. is a plan of the chain and screw shackles; the drag-chain being placed on the hooks of the carriages, the screw is turned round until the buffer heads are brought together. Mr. Booth's plan of buffers has been adopted on several railways.

Other plans of buffers have been invented to act with helical or spiral springs. Mr. Bergin of Dublin has a patent for an apparatus of this kind. An iron rod is made to pass from one end of the carriage frame to the other, and the connecting chains are attached to the buffer heads. The rod of the buffer passes at each end through a hollow tube, and is surrounded with a spiral spring, which bears against the tube, but cannot enter it. This invention has been applied to the carriages of the Dublin and Kingston Railway. Other forms of spiral springs have been applied, as that of Mr. Blackmore, to the carriages of the Newcastle and Carlisle Railway; but it would be of little practical utility to describe the various mechanical contrivances proposed for this, as well as for most points connected with railway practice on the advantage or disadvantage of which much discrepancy of opinion exists: indeed there is little occasion to enter into a minute description of the construction of railway carriages, if the principle on which their safety of action depends be understood, as they are constantly exposed to the observation and examination of every one. It has been recommended, that a more elastic construction of carriages, in which the axles might have sufficient play to enable them to adapt themselves to

curved tracks would be advantageous; and different plans have been tried for this purpose.

A plan has been suggested by Sir George Cayley to deaden the effect of a sudden railway train collision, by having a very large buffer fixed to the front of each engine, to be composed of a series of large cushions or mattresses well packed with elastic material. Another suggestion has been made, to have air-tight cylinders and pistons fixed to the part of the engine where the buffers are now placed, as the elastic property of the air would diminish the effect of concussion. Another suggestion has been made, to have a strong van stuffed with wool, cotton, caoutchouc, or some elastic substance, to run both in front and rear of trains.

THE GAUGE OR WIDTH BETWEEN THE RAILS.

The mechanical applications for rails and carriage-wheels having now been described, the formation of the railway track may be considered. This subject is one of those things connected with engineering arrangements, which has of late years attracted much public attention, and on which much difference of opinion exists; the points of dispute will afterwards be more

fully considered. All that is necessary to notice here is, that what is meant by the railway gauge is the clear distance the rails are placed apart, measuring between the inner rims of the rails.

In all the early-formed railways in this country the gauge was from 3 feet 6 inches to 4 feet. It was afterwards increased at the collieries to 4 feet 6 inches, and in the course of time was enlarged to 4 feet 8½ inches, which now forms what has been termed the narrow gauge, or the standard British Gauge, from its almost universal adoption: this may, in a great measure perhaps, be ascribed to this gauge having been adopted on the Liverpool and Manchester line. Some few miles of railway in Scotland, as the Dundee and Arbroath line, were at first laid down at a gauge of 5 feet 6 inches, but these have of late been gradually altered to the 4 feet 8½ inch gauge. The Irish commissioners have adopted a gauge of 6 feet 2½ inches on the Ulster Railway (Belfast and Armagh, Act, 1836); and on the Dublin and Drogheda line the gauge adopted has been 5 feet 3 inches.

On the Great Western Railway, between London and Exeter, 193 miles, Mr. Brunel, as is well known, for reasons which will be afterwards noticed, adopted a gauge of 7 feet, which is now

generally known by the name of the Broad Gauge. This gauge is now in the course of being farther extended into the heart of England, by the Act of last session of Parliament, for the Oxford and Wolverhampton Railway. It may be therefore kept in view, that there are only now two railway gauges in use in Britain—the broad, 7 feet, and the narrow, 4 feet $8\frac{1}{2}$ inches. The relative lengths constructed, or in progress, as given by Mr. Harding, in July 1845, are—

Narrow Gauge Railways.

	Miles.
Completed - - - -	1844
In progress - - -	614
	2458
Projected - - - -	6918
	9376

Broad Gauge Railways.

Completed, Great Western, Bristol and Exeter, Cheltenham and Great Western, Bristol and Gloucester -	278
In progress - - -	52
	330
Projected - - - -	1311
	1641

Thus making the proportion as $5\frac{3}{4}$ to 1. Almost all the railways projected since the above date are of the narrow gauge.

RAILWAY PASSING PLACES, POINTS, AND CROSSINGS.

In the railways first constructed in Britain, most of which were for private use in the mining districts, a single line of way formed the railway, the carriages getting off the main line when it was required that another train should pass, by means of what have been termed sidings, or passing places, namely, a branch diverging laterally from off the main line for a short distance, and then returning to it. In these railways the rule was for the loaded carriages to keep the main line, and the empty ones to cross to the siding till the others had passed. The point and switch rails, as may be seen on the older railways, were of most simple construction—a short piece of the rail turning on a pivot. *Fig.* 39. represents a crossing rail generally used on railways of this description. From the obvious inconvenience and danger attending points and crossings, especially if the carriages went at any speed, various contrivances were made to pass without interruption, or the necessity of altering the moveable piece of rail called a switch, which required much atten-

Fig. 39.

tion. The plan adopted where the traffic in each direction was nearly equal, was to have crossings of the rails laid in such a way at particular places that, at these, both trains diverged a little to one side, forming a circuitous course till they passed each other, dispensing with the moveable switch. A plan of this kind is much used in underground railways. Another mode is to have a spring switch opening to the wheels of the carriages, and allowing them to go on. The great object in these contrivances was to avoid the necessity of manual labour. *Fig.* 40. represents one end of a passing

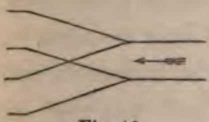


Fig. 40.

place, for a single line of railway, by which carriages, proceeding in opposite directions, diverge equally from each other at the same time. This plan may be worked without the necessity of moving the switch by the hand. The point rail at the one angle, and corresponding one at the opposite place of divergence may remain always open by means of a powerful spiral spring, moving back the point to its original position, when the carriages have passed, the points of the opposite angles being always kept shut. By another arrangement of the spring a contrary action may be made to take place, for when the moveable rail is pushed to-

wards the fixed rail by the wheels of the carriages the spring immediately closes it again. In other plans of crossings the passing-place simply diverges to one side of the main line, and returns to it again, the point opening to the retiring carriage, and returning by a spring to its former position. Mr. N. Wood describes a self-acting plan adopted at the Killingworth Colliery, where the loaded carriages keep by the main line and the empty ones diverge on one side, and return again when the former have passed; a spring switch being made to open to the wheels of the loaded carriages, and allowing them to proceed, while it makes the empty ones diverge to one side. The spiral spring is enclosed in an iron tube, and connected with the moveable rail, and by an arrangement of the spring it can be made to act against the rail, and be kept constantly shut, or the spring may be made to act the reverse way, and keep it open, and press it firmly against the fixed rail.

These contrivances of springs to move the point rails from the sharpness of the bends and joltings at concussion, are not so well adapted for double lines. Indeed, in the latter case, crossing places are not so much required, as a train requires only occasionally to deviate into a passing-

place, and the more seldom the better for safety. The point rails on lines for locomotive engines are considered to be more safely worked by the hand; it has, therefore, been properly viewed as a matter both of prudence and of necessity, that railways constructed for quick speed should have a double line of way. A single line for such purposes has, with a few exceptions, therefore, been almost entirely done away with; and it is now a rare circumstance in this country even to find one proposed, notwithstanding the temptation to adopt single lines from their less expense; although, as has been previously stated, many of the lines in America, one of them said to be of great length, have merely a single line of way.

In a double line of railway one of the lines is termed the up-line, and the other the down-line, the up-carriages invariably keeping on the one line, and the down-carriages on the other. When a quick train has to pass a slow train, going in the same direction, the latter has to go off the main line to a siding-place, and places of this kind and crossings are provided at different points of the line, or at stations. At most of the termini of railways four lines are laid down with crossings; and turn-tables are provided for the facility of changing the carriages on the lines.

Fig. 41. is the plan of a common crossing, running obliquely across a double line of rails. The angles are shown, more acute than they are in reality made, for sharp angles could not be worked with safety on railways, owing to the great shock in passing, creating a liability to throw the wheels off the rails. The angle of railway crossings for great speed should not be more than from 2 to $2\frac{1}{2}$ degrees, but for slow speed the angle is commonly 6 to 7 degrees. At the points of intersection of the rails grooves are provided for the flanches of the wheels, and guard rails are placed within the line, to keep the inside flanch from getting off the rails. So important for railway safety is the setting of the switches, as the least neglect may occasion the most serious accidents, that some railways have a signal apparatus affixed to them, which indicates to the driver of the train as he approaches the exact position of the switch.

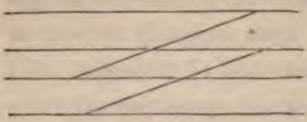


Fig. 41.

The method in use of moving the crossing points on railways is much the same as that first adopted on the Liverpool and Manchester line. Two cast-iron plates about 9 feet in length are fixed on the blocks or sleepers, and have a

single moveable rail on each plate, turning, at one end, a few inches on a joint or centre. The butt-end of this meets two rails (a little separated), which also rest on one end of the plate. The two moveable pieces are connected together by an iron rod which moves them laterally to each side of the fixed rail, so that in an instant the train can be diverged off the main line. Another plan acts the reverse of this; it is a loose rail in the common way, turning on a joint, and the sharp end of the point carries onward the carriage wheels on the intended track. Two short pieces of both the moveable and fixed rails are placed upon a cast-iron plate.

On railways where steam power is adopted, the moveable points are worked by means of a lever and connecting-rod, the handle coming through a square cast-iron frame placed on the ground clear of the rails: by the simple drawing back the lever, the point is moved; and when the attendant slackens his hold, the point returns to its original position.

Instead of the square plate, the plan on several railways is to connect the turning-rod with a small cast-iron pillar, firmly set up. A vertical spindle, passing through it, turns in a socket at the lower end: near the bottom of the spindle a

sheave is placed horizontally, fixed on a false centre, with an iron ring working round the sheave, forming the common eccentric motion: from one side of the ring a horizontal rod is connected by means of screws with the rod which turns both the points or loose rails. The apparatus is entirely enclosed, and nothing except the pillar and handle is seen. The whole of the Great Western Railway is provided with very neat pillars of this kind. Examples of the arrangement of the crossings at the termini of railways may now be seen at almost every large town. At the Euston Square station of the London and Birmingham line, four lines of rails are laid down, as also at the goods' depôt, about two miles distant, between Camden Town and Chalk Farm bridge, near the Primrose Hill tunnel. At the latter place the general arrangement of railway crossings may be seen, and the danger which so obviously and necessarily attends them, both the up and down lines being intersected; eight or ten crossing-points or switches are seen from Chalk Farm Bridge within the space of a few yards; and as all these require to be set and turned by the hand to put the trains on the right track, one may easily conceive the vigilance and care requisite in their management, notwithstanding the facility with which, from the

apparatus already described, they can be changed. Perhaps there is nothing connected with railway practice in which more imperfection exists, or is so fruitful a source of danger. So much so is this the fact, that many engineers have long considered that there never can be entire immunity from risk at these crossings until there be introduced a self-acting switch or points opening themselves by the action of the wheels of the carriages. From the rapid speed, however, of railway trains, any contrivance for this purpose must be attended with practical difficulty. Although, therefore, there is considerable risk from the neglect of these when opened by hand, still there must be a confidence given to the driver as he approaches (which he would not feel from the former plan, from the apprehension as to the derangement of the apparatus), in daylight, to find the turn-point at his station, and at night, that the signal indicates that the points are properly set. The danger arising from these not being rightly placed must be apparent, when it is considered that the least neglect might send a train diametrically the opposite way intended. It must likewise be equally obvious that the fewer crossings used, the safety must be the greater; and when crossings do exist, they should not intersect the main line of transit.

The danger attending the intersections of the main line is fully illustrated at the Camden Town station. The goods' station lies to the right of the main line (going out of London); hence luggage vans have to cross the down line before they can get on the up line: they are consequently always liable to be run into by the down trains, from the least derangement of time, as lately happened, and was productive of fatal consequences. The danger arising from an arrangement of this kind must be apparent, and could be removed at a little inconvenience, by separating entirely the up and down goods' departments, and making one set of warehouses, from which the down goods proceeded at once upon the main line, and another set of warehouses in which the up goods should be received without having diverged from the main up line, thus preventing the luggage vans crossing the lines: had such an arrangement been in existence the late accident could not have happened.

An accident has just occurred from the same cause at the Bristol terminus, where a train from Gloucester ran into the Exeter luggage train, while the latter was passing from the Bristol and Exeter to the London line, and seven trucks were smashed to pieces. In lines therefore worked

with locomotive engines, where great traffic exists, were the goods' department to be entirely separated from the passengers' one, both safety and convenience would be consulted. This, indeed, could only be at first done by much additional outlay, and made perfect by forming perhaps a third or even a fourth line of rails, the goods' traffic being entirely confined to the lines made for it. Indeed, from the difference of speed adopted with different trains, such a plan as this seems the only one to avoid the danger of collisions by trains being run into. Were a third line of rails formed at every railway where express trains are allowed to run, to which they were confined, great additional safety would be given, as passing-places must be ever attended with much uncertainty.

A very opposite view to the above was entertained by Mr. F. Wishaw, as to the means to prevent collision, and at the same time enable railways to be formed at little expense. He proposed to have only a single line of way throughout, whatever be the amount of traffic; and to start at every hour in the day from terminal and principal intermediate stations, exchanging the trains by means of turn tables. This singular scheme he termed the reciprocating system; but from

its inconvenience, and the vigilance of management required for working such a plan, it is not likely to be adopted.

TURN-TABLES.

Those very dangerous crossings which exist on many lines should, if possible, be removed, whereever locomotive power is employed; indeed, they are not in general necessary, especially near stations, as the goods' warehouses are usually built at the final terminus. The heaviest carriages are easily moved from one line of way to another by means of the useful and clever invention called the turn-table or plate. This consists of a circular cast-iron table turning round upon rollers, having four iron rails formed on it, placed at right angles, of the same gauge as that of the line, and set to the same level; when the carriage passes on to the table, it is wheeled round, and may either be entirely reversed, or, by turning it a quarter round, so as to be at a right angle with the line, the carriage may be run on to another line of rails. The tables can thus transfer a single carriage in a short space of time from one track to another, or add it to, or take it from, the train; or an engine can be entirely reversed in a few minutes.

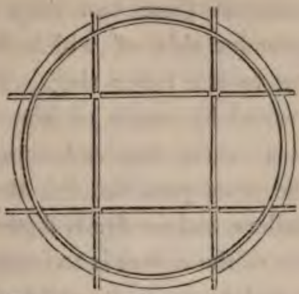


Fig. 42. Plan.

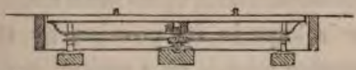


Fig. 43. Section.

The turn-plate (*figs.* 42. and 43.) is constructed by making a circular hole, built with masons' work, of the size to receive the table, from 10 to 12 or more feet in diameter, according to the gauge of the rails and length of the carriages; those of the broad gauge being much larger in diameter than the narrow. On the floor of this pit, eight or more stone blocks (*fig.* 43.) are placed round the circle, and on these, cast-iron chairs are fixed, in a similar manner to those used for rails. In these chairs an iron circular ring, about $2\frac{1}{2}$ inches broad, is laid, with the outer edge of the upper side slightly inclined downwards, and on the under side of the table there is another ring of the same

diameter; between these two rings iron rollers revolve, the under side of which has a bevel corresponding to the lower ring. These rollers are turned round by means of iron arms, which radiate from a centre ring embracing a vertical spindle. The arms pass through the middle of each of the rollers, and are firmly fastened to them. The intention of the rollers is to carry the weight of the table, and to move it easily, as the under ring of the table turns upon their circumference. The table is kept in its position by the centre spindle, turning with it on a socket, but not supporting the weight. There is an outer iron ring the same diameter as the table, and forming (should the platform be made of timber) an edge to it. This ring is raised above the level of the arms of the rollers, and within it the floor is placed upon which the rails are laid. The platform of the table is, however, generally now made entirely of cast-iron, with rails raised on its surface. A ring of corresponding diameter surrounds and forms a margin to the table, and the ends of the rails of the line of way rest on it, and abut those on the turn-table.

To describe the numerous mechanical contrivances connected with railways would fill volumes. One, not the least interesting, is the

water-crane, which consists of a cast-iron pillar, through which the water passes, having a hose to supply water to the engine: they are planted on different parts of the line. These cranes revolve on a centre, to bring the hose to the tank, and to be turned from off the line when not used; and means are taken to prevent the water freezing. The mile-mark is another useful contrivance on railways, by which every quarter of a mile may counted, and the rate of speed ascertained by the travellers.

DESIGNING A LINE OF RAILWAY.

Having now described the mechanical contrivances required to form the track of the railway, (and it may have been observed how much skill and perseverance have been displayed in bringing these to the maturity they have already reached,) the formation of the line may be shortly considered, although it is foreign to my purpose to enter into minute details, or a disquisition on this branch of railway practice. However, a synopsis or condensed view of a subject in which so many are interested may be useful. Every one, indeed, can easily have a general idea of the principles upon which railways are usually constructed. It may be said,

without much fear of contradiction, that the great point to be kept in view in railway planning, with the amount of engineering knowledge on this subject already acquired, is to have a clear and definite view of the object for which the railway is to be constructed; the motive power which is intended to be employed; and likewise a precise idea of the rate of speed which it would be required generally to be worked at; whether the railway is to be planned for goods as the main object of traffic, or whether chiefly for passengers; or whether to be adapted for both purposes at a moderate rate of speed. Almost every point connected with the formation of a railway hinges on the motive power and rate of speed.

Had such points been clearly wrought out and determined on by engineers, or by railway companies, before the undertaking was commenced, even in making surveys and taking levels, many examples might be given showing how much useless expenditure might have been avoided. Where a slow speed is required, with a light traffic, difficult gradients might be overcome even without an assistant engine; and thus the expensive and Herculean labours might be avoided of cutting miles through hills or solid rocks — forming dismal tunnels and precipitous embankments. On

the other hand, a railway formed with the view of carrying out a rapid movement, and taking loads of goods in hourly succession, must have every engineering part of the line adapted to the working of it. Thus, the radius of a curve which in one case might be admissible, in the other would be dangerous, and must be enlarged, or dispensed with entirely: in the one case steep gradients would be of little consequence, in the other exceedingly injurious; while a curve placed at the base of an incline in the latter would be still more mischievous and absurd. For heavy traffic and great velocity the excavations and embankments must, therefore, be proportionate in width — the viaducts in strength — the bridges and tunnels in elevation and width — road-crossings avoided — and while the gradients are adapted for such increase of speed, the strength and stability of the rails must bear a corresponding proportion.

Too often, perhaps, from overlooking these preliminary points, have railways been constructed ill adapted for the rate of speed, and weight, and number of the trains worked on them. Had the present quick rate of speed been foreseen, might not the steep inclines on the Liverpool and Manchester railway (at Whiston, 1 foot in 96, and at

Sutton, 1 in 89) have been avoided, which, in spite of all the advantages of the increase of the motive power, form permanent impediments to rapid transit? And, in a similar manner, would not the curves of short radii which exist on many lines have been avoided?

In the construction of railways, the cuttings and excavations — that is, the formation of the line of way through elevations, and their perforation, where requisite, with tunnels — the filling up of deep ravines, or the forming of embankments — are all points that evince the talent and skill, and test the experience, of the engineer. As the main object is to bring the line of way as near to a level as possible, by the judicious planning of the line many thousands of pounds may be saved. Engineering in these days has assumed a new feature from bygone times. To be a railway engineer, not only requires an accurate eye to take up the general aspect of the country, but at the same time to have a clear conception of its geological character. The level above the sea is too often overlooked, and considered a secondary matter; but it is all-important, as all main trunk lines for commercial purposes ought to have a branch communication with some sea-port. Nothing, indeed, is more common than to find

people suppose the summit of an inland district is greatly above the sea level, when in fact the rise is often inconsiderable. There are, perhaps, not many countries, where the general trending of the mountains is understood, through which railways could not be carried. No doubt "railway difficulties," as they are quaintly termed, which always more or less exist, are increased in hilly countries; but that route, which but a few years ago would have been deemed impracticable, now presents few obstacles to engineering skill.

In laying out a line of railway through a country, the gradients have been properly considered an important point in the adoption of the particular line. The word gradient, now in so common use, is well known to mean the proportion of feet of ascent or descent in a mile. An inclined plane is of course understood to mean every plane which is not level; and it is usual in describing railways to make use of the term inclination for ascent, as an incline of 1 in 101, or an ascent rising one foot in one hundred and one feet, which is the same as a gradient of 52 feet per mile. Beside the consideration of the gradients on the route, another principle of great importance to be kept in view is, to shorten the distance as much as possible between places to which a direct

communication is required. The result of experience in railway formation has already shown that circuitous routes not only increase much the expense, but do not afford the advantages required; beside which, the adoption of a curvilinear route too often, instead of a straight line, has had the effect of injuring the efficiency if not the general safety of the line.

The numerous plans of railways now before the public proceed, therefore, chiefly on the principle of a direct communication, and it is considered better for smaller towns to have a branch directly to the larger ones, than that a railway should perambulate a country, and diverge for their accommodation, at one point at a tangent, and at another by a semicircle, from the straight line.

It need hardly be observed, however, that in several cases it is impossible to avoid a curvilinear route, as in approaching domains, although there is no doubt that in many instances the objecting parties would ultimately obtain most advantage by permitting the straight line to have been adopted. Besides the advantage of having railways formed in direct, rather than in circuitous routes, a new feature seems to introduce itself into railway arrangements, which does not yet appear to be sufficiently understood: this is, the advantage of

having short lines of railway from town to town, and village to village, under local management, on the presumption that turnpike roads will soon entirely merge into railroads. On this plan the trunk lines proceeding in long distances would have feeding branches from every district; and one town being connected with another over the whole kingdom, would afford facilities of communication the present system never could give.

The want of having direct routes of railway communication fixed throughout the country has by many been considered an error in the railway system; which, however, from the number of lines, cannot prove any impediment either to general traffic or the convenience of passengers. In Ireland, commissioners were appointed to consider the subject of railways for that country, and certain lines have been proposed in conformity with their report; but from the limited extent of railways yet formed, there is not data sufficient to form any decided opinion of the system. Most of the continental railways have been planned under government control, but in Britain commercial enterprise seems likely to achieve every object desirable in respect to railway transit, and multiply the lines to accommodate every district in the United Kingdom.

As, in planning any railway whatever, it is next to impossible to obtain a direct level, the object of the engineer is to arrange the gradients of the line in such a manner as to approach to a level, for nothing will tend more to the perfection of a railway than that the track over which the wheels are to run should be smooth, straight, and level, which arrangement is, in every instance, the preferable one. But as it is absolutely necessary in many localities to ascend considerable acclivities, and to descend again to the former or even a lower level,—or when one terminus is considerably elevated over another, as on the Edinburgh and Glasgow line, it becomes necessary to descend from the level of the one to that of the other. Engineers very naturally differ in opinion as to the best methods of overcoming such difficulties. One plan adopted has been to distribute the rise and fall as equally as possible throughout the whole line; and another method has been to concentrate these on a few steep points, and to make the other parts of the way as level as possible. The London and Birmingham railway affords an example of the former, and the Liverpool and Manchester of the latter. Some have strangely considered that when the line of way is undulated (the Hull and Selby affords an example of this

profile), it is preferable to a perfect level, as the gravity which aids the descent increases the momentum of the ascent, thus equalising the amount of tractive force; but as the amount of gain is however very small in short planes, this method of arranging the gradients of a line is not likely to be entertained unless from peculiar circumstances.

It is now generally admitted that, in order to attain an economical working line where considerable deviation from the level must exist, that there must be some similarity or equalisation of the general gradients of the line; or in other words, that when the traffic of a railway is nearly the same from both ends of a line, the degree of inclination is of less consequence as respects the working expense, provided the loss in gaining the general summit would be compensated by the gain from the assistance of gravity in the descent. In accordance with this view on most railways on which a considerable summit level has to be reached, the plan is adopted of having a series or planes gradually rising, and a corresponding series descending. The Grand Junction affords an example of this arrangement: on it there are 15 ascending, 10 level, and 23 descending planes. No railway, however, constructed on this plan,

can be deemed perfect, without breaking a long inclination with intermediate level planes, as considerable danger must always exist from the momentum which a heavy load acquires in descending uninterruptedly a steep descent. The Eastern Counties Railway, at Brentford, incline, affords an example of the want of this arrangement, there being no level plane in the nearly three miles of descent; 1 foot in 100, or a gradient of 52·8 feet per mile.

To attain the objects of railway formation now pointed out, from the varieties of the surface of a country, vast expense will often be incurred; valleys must be filled up, rocks cut through, viaducts and bridges formed; and even should a district be comparatively level in some instances, as in the Edinburgh and Glasgow line. verv expensive works in a short distance occur: thus the works, in this 46 miles of railway, are much more numerous and expensive in proportion than those on nearly the same level plane of 117½ miles of the Great Western.

As these expensive works have generally been formed for the purpose (at least in reference to the Edinburgh and Glasgow railway) of obtaining a level way, as the ordinary gradient on this railway is 1 in 880, it becomes a matter of much importance, as regards not only the original outlay, but the

safety in working of the railway, whether it is better to adopt the plan of concentrating the fall, as in this case, on one steep point, or to distribute the rise and fall throughout the line by adopting a steeper class of gradients. By the latter plan, there cannot be a doubt, great sums might have been saved on railways already constructed. When competing lines are proposed through any district, in coming to the determination to give a preference to one plan over another, the choice will generally be regulated by the convenience and utility of the line, and that the engineering arrangements present no obstacles to the prospect of success. It is of importance, therefore, to consider whether by a saving of original expense in the formation of the line, but attended with perhaps the risk of permanent inconvenience in working it, or whether a more expensive outlay at first to obtain a level, is the most advantageous plan.

EFFECT OF RESISTANCE OF CARRIAGES ON RAILWAYS.

In order to consider this question aright, certain facts in reference to the effect of resistance of carriages on railways must be kept in view; for

it is indisputable that with the same *motar* applied, the speed is reduced just in proportion to the ascent, until the impelling power ceases to be be longer available. It has already been remarked that the resistance of carriage wheels on a common road, from friction and roughness of the surface, is so great that the gravity which operates as a constantly retarding force in moderate inclines becomes less observable; whereas on the smooth surface of a railway of the best construction, over which the wheels glide, the loss of power is so much reduced in amount that the least departure from the level makes the full force of gravity or the weight of the train to bear against the inanimate impelling force. Notwithstanding the science of these times, it may be questioned, if the full importance of this fact in railway formations has been considered. But it brings the simple question prominently in view, whether it is better to take the direct course, though more inclined, than to take the longer one and keep the level.

In considering this point, the difference between the tractive force exercised on a level and an ascent must be estimated. Engineers have differed in the absolute amount of opposing force which carriages on railroads have to overcome before the

moving power is available: one thing is certain, that there is in operation at all times a uniform and constantly retarding force, arising from gravity, friction on the rails, attrition of the axles, and the action of the wind. On a level plane the resistance to the draught or movement of the train has been estimated at 7 to 8 lbs. per ton. According to the experiments of M. Pambour, on the Liverpool and Manchester railway, 8·3 lbs. was the friction per ton, or the 280th part of the weight. Mr. N. Wood is inclined from his experiments to estimate it about 9 lbs. per ton, or the 240th part of the weight. Taking the resistance to be overcome by the motive power on a level railroad at the lowest estimate, 7½ lbs. per ton, (or nearly the 300th part of a ton,) for every 7 feet of rise in a mile, 3 lbs. per ton would be added to the opposing force of traction; so that 14 feet of rise, or 1 foot in 337, would make the amount 6 lbs., and 1 in 300, or 17½ feet of rise in the mile, would double the resistance to be overcome; or add 7½ lbs. more weight per ton to be pulled; — 35 feet per mile, or 1 in 150, would triple, and 52¼ feet per mile, or 1 in 100, quadruple, the resistance to be overcome, and so on. Taking therefore the resistance which a train has to overcome on a level plane at the

lowest estimate of from 7 to 8 lbs. per ton, a train of 60 tons would require a power to be exerted of 420 or 480 lbs. or 7×60, or 8×60; and keeping in view the effect of gravity, and that a plane of 1 foot in 100 adds one ton to the downward tendency, the resistance by gravity on an ascent of 1 in 50 would be 44·8 lbs. for each ton, and for 1 in 90, 24·88 lbs. This on 60 tons would amount to 1493 lbs. additional power to be drawn, which increases the opposing force from 60 to 186 tons. And should the resistance on a level be taken at 8 lbs., a load of 112 lbs., including carriages, on a level would oppose to the tractive power 896 lbs.; but on an inclined plane of 1 in 135, the increase from the effect of gravity would be 2686 lbs.

It necessarily follows that this increase of resistance to be overcome on an incline must be attended with much waste of power: so much so is this the case, that it has been estimated that to ascend an elevation of 20 feet, or 1 in 264, as much power is exerted in one mile in length as would draw the same load double the distance. Much loss of time must likewise thus obviously arise in working up steep inclinations, even with all the advantage a powerful motar can give, without the aid of auxiliary power.

The fact being incontrovertible that every de-

parture from the level is attended with a greater exertion and certain waste of power, and that, to overcome it, and to preserve the same velocity as on a level, powerful assistance is required; in determining the formation of a line, the question resolves itself into this, — whether it is better to expend this waste of tractive force than to cut down or through rocks and fill up valleys, and form tunnels and viaducts. No doubt can be entertained that saving of expense must be a primary object, and there will be little hesitation in giving the preference to a plan by which any expensive works can be saved, and still the same safety of working preserved. The point, at present, is not the difficulty of ascending steep gradients from the great increase of power given to the impelling force, as will be afterwards shown, but it is, how far this plan can be prudently carried. This is a matter, however, that can only be determined by the judgment of the engineer in the particular route. It is for his consideration how far, for the waste of power, he can avail himself of the counter-balancing effect of gravity; and some estimation should also be made of the general purposes of the railway, and rate of speed to be adopted. There is no doubt of the fact, for it has been experimentally ascer-

tained, that in railways formed with an equalisation of ascending and descending planes, the compensatory effect has produced the same expenditure of power, as if the plane had been level. This result has been in part attributed to the diminished resistance of the air in going up the ascent, but unquestionably it is nearly entirely the effect of gravity increasing the velocity of the descent. It is, therefore, certain that railways can be designed to work advantageously with a similarity of, or equivalent, gradients, and it is a matter of consideration how far this system can be pushed.

Beyond a certain point it cannot be carried with advantage, wherever the incline has to be surmounted by the aid of auxiliary power. To the positive waste of power by the force of gravity, when off the level, must be added the additional expense and inconvenience of working the auxiliary; or when the incline cannot be surmounted without assistant power, still, if the effect is to reduce the size of the trains or the maximum load carried on other parts of the road — for the weight must be proportioned to the power — or to require the unnecessary expense of carrying forward over the line a greater tractive force than would otherwise be requisite; in both of

these cases, the formation of inclines which require to be so worked, cannot be economical. The rule may be therefore laid down, that so long as the degree of inclination does not materially reduce the speed, it is of little consequence, and it cannot prove of much injury. There is scarcely any doubt that the adoption of a general steeper ruling gradient throughout a line would, in some cases, have been attended with advantages, and would be often preferable to descending very precipitous inclines to reach a level. The question, however, as to the degree of inclination which can be adopted with prudence and safety cannot be properly judged of without taking into consideration the effect which the descent has upon the carriages, as well as the ascent. This brings into view what has been properly termed the angle of repose, — which means, when the wheels of a carriage will stand upon an incline without slipping, or the point where the gravity and friction are equal. This angle was long taken at about 1 foot in 280, or a plane inclining at the rate of 18 feet 10 inches per mile, if the friction of a ton on a level was taken at 8 lbs.; or, the inclination of 1 foot in 320, or 16 feet 6 inches per mile, if the friction was taken at 7 lbs. From recent experience it appears that the views formerly enter-

tained of the practical effects of railroads were not sufficiently understood; for though the angle of repose may be correctly applied to some carriages, on others it has differed; for while one carriage has been found quiescent on an inclination of 1 in 280, one engineer states that he has known a carriage to run down an incline of 1 in 330 at the rate of 4 miles an hour, acquiring a velocity of 8 miles. It was also thought that, at a speed of 40 miles an hour, the angle of repose would be the same as if the speed were different; but it has been found that, instead of the angle being invariably the same, 1 in 250 or 280, it necessarily increases. The velocity acquired by a train in descending a plane increases in an equal ratio as the resistance of the ascent; for, according to the laws of inclined planes, the resistance or weight increases as the perpendicular height of the plane is to its length. Thus is at once perceived the danger which is always present in going down a rapid descent, and the care and attention necessary for safety to regulate a uniform velocity. The importance attached to the regulation of this velocity could not be overlooked, even in arranging the gradients of any railway; hence portions of the lines, at either end, called the "Terminal plane," are usually made on

a slight ascent to the terminus, to check the velocity of the engine when arriving, and also aid the motion of the train when starting.

BREAKS.

Where very steep inclines exist on railways, a powerful drag or break is requisite to stop the carriages in case of an accident; and often very serious ones have happened under the stationary engine system. Many plans of breaks have been devised to retard the descent of the trains, both on inclines worked by stationary and locomotive engines. Heretofore all these breaks have been made to act, whether moved by the action of the steam power, or by the hand, on the vertical principle. The break, consisting of a block of wood bolted to an iron plate fixed to a connecting rod, is placed on the inside of the outer frame of the carriage, having a single or double lever working on a fulcrum, and when the handle is pressed outwards or screwed down, the connecting rod presses the face of the break against the carriage wheel.

Mr. R. Benton, of Birmingham, has lately taken out a patent for a very powerful and

apparently effectual drag, which operates in a *lateral* direction against an independent fulcrum purposely prepared on the outside of the lines of rails, which, in the opinion of many machinists, is capable of stopping or regulating the progress of a train in any circumstances. Whilst, therefore, a self-acting drag is most desirable in railway transit, there can be no greater error in the construction of a railway than to have very steep inclines, which should require its action, and every care ought to be taken to avoid them.

Among other contrivances, a self-acting drag has been proposed by Mr. Thornton. He proposed a rope to tow the carriages connected with the engine, and that the guard, by means of a contrivance for the purpose, shall cast loose the rope, and that no sooner will this take place than the break will press on the carriage wheels so as shortly to stop the train.

A good deal of interest was lately, November, 1845, created in Farringdon Street, London, by the exhibition of a very simple break, which may be applied to the wheels of railway and of common carriages, and of other machinery, stated to have the effect of stopping a train (without the slightest reference to the speed) almost im-

mediately. The patent for it belongs to the Rev. Mr. Maberley, of Stowmarket.

RAILWAY GRADIENTS.

From the preceding observations an opinion may be formed of the advantages or disadvantages attending the system of adopting steep gradients, and of keeping as near as possible to the level and straight line. There can be little doubt, the more the subject is investigated, that the latter will be found the true principle of railway formation, both for safety and utility; and when gradients can be brought not to exceed 16 feet per mile, or 1 foot in 330, the railway, although at first more expensive, will ultimately have the fewest drawbacks. In many cases this cannot be attained; and it is proper to state that some engineers have considered making this gradient the maximum not always desirable; and there are many examples of railways which have been successful with steeper gradients. The North Union railway illustrates the saving with which this system can be attended. It may be useful to observe the gradients which have been adopted on particular lines. For facility of arrangement, gradients have been divided into

heads, under which existing railways are simply classed.

Mr. F. Wishaw has made the following classification of railways: —

1st class of gradients, where the minimum rising of the line of way is 16 feet per mile, or an inclination rising 1 foot in 330.

2nd class gradients, where the minimum rising is 52·80 feet per mile, or an inclination rising 1 foot in 100.

3d class gradients, where the minimum rising is 88 feet per mile, or an inclination rising 1 foot in 60.*

According to this arrangement, the following railways would be classed: —

* Mr. Wishaw gives the following places in London, by which the degree of inclination may be judged: — Greatest rise of Holborn Hill is 1 foot in 14¾, and the average rise 1 foot in 24. The greatest rise of Blackfriars Bridge, 1 in 16½; ditto London Bridge (Surrey side), 1 in 27; upper part of City Road, 1 in 40 feet, or about 128 feet per mile.

Length of Miles.	Name of the Railway, and prevailing Gradient.
1st class.	
112	London and Birmingham, prevailing gradient 16 feet, or 1 in 330, with the exception of the inclined plane at Camden Town, 1 in 75, now worked with locomotive engines.
48	Midland Counties, gradients 1 in 330, 354, 389, 420.
38	Birmingham and Derby Junction, no plane greater than 1 in 330.
45	Great North of England, from 1 in 349 to 1 in 11,000.
27	York and North Midland, prevailing gradient 8 to 16 feet, or 1 in 660 to 1 in 330.
193¾	Great Western, in 117½ miles, (with the exception of two inclines of 1 in 100, or 52·8 feet per mile, one at Wootton Basset, and another at the Box tunnel, both worked by locomotive engines:) there is no gradient steeper than 1 in 344, or 15·35 feet, and this only for a short distance: the prevailing gradient is only 6½ feet per mile, or about 1 in 817: the next gradient is 8 feet.
56	London and Brighton, prevailing gradients 20 feet, or 1 in 264, incline 1·123 to Merstham, to Horley 1 in 260.
	Lancaster and Preston, prevailing gradients about 10 feet, or 1 in 500.
88	South Eastern, London and Dover, prevailing gradient about 10 feet, or 1 in 330.
78	South Western (London and Southampton), between first and second class, prevailing gradient about 21 feet or 1 in 250.
31	Hull and Selby line, undulating gradients 1st class, but some second.
31¾	Dublin and Drogheda, 1 in 267 to 329.
46	Edinburgh and Glasgow, prevailing gradient 1 in 880, with the exception of a very steep

Length of Miles.	Name of the Railway, and prevailing Gradient.
1st class.	incline at the tunnel near Glasgow 1 in 43, now worked by locomotive engines. (This railway is one of the most uniformly level lines which has been made.)
51	Glasgow and Ayr, the steepest rise is 1 in 400.
22½	Glasgow and Greenock, the steepest rise is 1 in 330, at Bishopton.
2d class.	
82	Grand Junction, general gradients good, 1st incline 1 in 85, 1 in 100, 1 in 177, 1 in 330.
60	Manchester and Leeds, average inclination 1 in 260, steepest incline 1·182 for 6 miles.
10	Manchester and Bolton, inclines 1 in 160, 200, 239, 274.
53	Birmingham and Gloucester, the prevailing gradient about 17½ feet per mile, or 1 in 300 There are several ascending and descending planes of this inclination: the very steep inclines at Lickey, 1 in 37 to 1 in 84, are worked by locomotive engines.
60	Newcastle and Carlisle, 1st incline 1 in 106, one long ascent to summit level and descent, 1st incline 1 in 176, 216.
25	Stockton and Darlington, gradients generally steep 128, 204, 233, 427, ascending chiefly from Stockton, worked by stationary engines, inclines 30, 32, 33, and 104.
	Belfast and Portnadown (Ulster Railway), prevailing gradient 26·4, or 1 in 200.
10¼	London and Croydon, gradients good, except the incline at New Cross, 2¾ miles to Dartmouth Arms, 1 in 100, worked by assistant engines.
30	Liverpool and Manchester comes almost under third class: the inclines are 1 in 89, 1 in 96 1 in 45: other gradients good.
6	Dublin and Kingston, the steepest incline is 1 in 440.

Length of Miles.	Name of the Railway, and prevailing Gradient.
3d class.	
24	North Union, 10 planes inclining at the rate of 1 in 100.
16	Leicester and Swannington, some very steep inclines ascending and descending 1 in 17, 1 in 29, worked with fixed engines; also inclines of 1 in 147 and 1 in 230, &c.
5	Sheffield and Rotherham, ruling gradient 1 in 78.
13	Durham and Sunderland, entirely worked by stationary engines.
2 miles 8 chains	Edinburgh and Newhaven, a steep incline in a tunnel 1 in 27·45, proposed to be worked with locomotive or atmospheric power, second plane 1·160, third plane 1·360.
6	Canterbury and Whitstable, divided into 5 planes, some of which are inclines of 1 in 31, 1 in 46, 1 in 50, and are worked with stationary engines.
28	Maryport and Carlisle, very steep inclines, from 1 in 27 to 1 in 97.
9½	Dundee and Newtyle, inclines 1 in 10, 1 in 13, and 1 in 25, very steep, worked by fixed engines, and the levels by locomotives.
8¼	Edinburgh and Dalkeith, and branches, second class, one half line 1 in 234, branches 1 in 69, and 1 in 51½, incline at tunnel 1 in 80, worked by a stationary engine, the rest by horse power.
17¾	Brandling Junction, worked by locomotives, and an inclined plane by stationary power.
9	Bolton and Leigh, 2 planes 1·30, and 1·49, worked with stationary engines, rest of line by locomotives.

The preceding classification does not always, however, afford a correct idea of the working of the line: for example, the Liverpool and Manchester, which comes under the 2d or 3d class, has no gradient exceeding 1 in 849, with the exception of the two inclines near Rainhill. In the older railways in this country, it will be perceived the gradients were generally much greater than those of later construction: the cause of this is obvious, for they were made for the use of stationary engines, which was the only means then known to gain the summit level. Within a few years the stationary system has in many railways been disused — for gradients which were formerly impracticable with any other than fixed power are now easily ascended with locomotives — which has led to the return to the plan of adopting steeper gradients throughout a line; and what was formerly termed a stationary engine plane, has now, in many instances, become a locomotive plane.

Where fixed engines are used, the usual method is for the engine at the top of the incline to draw up the train or waggon by means of a rope running round a drum and cylinder attached to the engine, while the return waggons, or descending train, proceeding down by their own gravity, carry back the rope. On other lines self-acting

planes were used; or when the descending weight preponderated, the gravity of the descending carriages drew up the ascending carriages to the apex of the plane — to the pits' mouths. The very steep inclines on the Leicester and Swannington railway are worked in this manner; and chiefly likewise the planes at the Ballochney railway in Scotland.

The Whitby and Pickering railway, which is very tortuous, is worked by horse power, except one plane, on which a tank of water mounted on wheels is made to descend the steep incline by gravity, and to assist the ascent of the trains. At Brassleton fixed engine plane, on the Stockton and Darlington line, where there are inclines on both sides from the summit a single coach is drawn up by a rope attached to a fixed engine, and let down by gravity, drawing the rope after it. The Clarence railway is worked partly by horse power — the trains descending by their gravity — the horse returning to the bottom of the incline in a stable attached to the trains. The Canterbury and Whitstable railway was one of the first railways made in the south of England, worked by stationary and locomotive power. The first act was obtained in 1825: but it was not constructed till 1830. The fixed engine, of 25

horse power, on Tyler Hill, an incline of 1 in 48, will raise 35 tons at the rate of $7\frac{1}{3}$ miles per hour. The inclinations on this railroad vary from 1 in 31 to 1 in 50. The steep inclines on the Dundee and Newtyle railway are also worked by stationary engines in a similar manner; and on the Edinburgh and Dalkeith railway, for which an act was obtained so late as 1826, an incline of 1 in 30, is worked by a stationary engine, the descending carriages carrying down the rope; the rest of the line is worked with horses. Various other railways unnecessary to mention are worked by means of stationary engines throughout the whole or part of the line. The Durham and Sunderland, 13 miles in length, is entirely worked by fixed engines. It consists of 8 planes, varying in inclination from 1 in 60, to 1 in 264. The power of the engines is from 42 to 85 horses.

CURVES ON THE LINE OF RAILWAY.

Some railways in this country are almost entirely curvilinear, as the Newcastle and Carlisle railway, already noticed, which is one continuous series of curves and recurves of short radii. Rail-

ways on this plan are not again likely to be constructed. Several of the curves are about twenty chains, or a quarter of a mile radius. When curves are at all quick, they not only limit the speed of the engines, from the tendency of the wheels to pursue a direct course, but even should they be of large radii, every one must be aware that the probability of the carriage wheels not being thrown from the rails, in taking the curve, will depend much on the rate of velocity at which it is taken. The oscillation and jolting of the carriage is considerably increased as the carriages take the curve; and so much so is this the fact on all railways, that a person without looking can tell the difference of motions in the carriage. Suppose that the carriage has a descent before it reaches the curve, such is the increase of momentum given to it, that the tendency it has to go in a straight-forward course, or in a tangential direction, is increased; and, although the engine be partially slowed, every carriage comes full upon the engine at the time it has taken the curve in a direct line onward. The safety will therefore depend on the flanch of the fore wheel, and the weight of the carriages on the rails. From the lateral strain given to the outer rail, if it were the least imperfect, or to swerve, or if any

yielding were to take place — should the least inequality of surface exist, or any impediment present itself in this dangerous position, the wheels by the rocking and twisting of the carriages, as may be seen by looking along the line of the carriages, would easily be thrown off the rails.

Curves of short radii have been too often permitted to be made; indeed the Board of Trade does not require companies to state any curve of a less radius than a quarter of a mile: but there can be no doubt entertained by any person who will investigate the subject, that so long as railways are used for great speed, a curve even of a mile may be attended with danger, which is tenfold increased if allowed to exist at the base even of a moderate descent; for the curve, added to the ascent, increases the resistance so much, that a curve of three quarters of a mile in radius, on a rise of 1 in 330, will reduce the speed to about one half. Many accidents have proceeded from curves at the base of the descent, when the high velocities are considered at which trains now run.

In an accident lately on the Eastern Counties railway, one witness, who was standing close to the line when the train passed, and could easily perceive its action, speaks distinctly to the great oscillation or rocking motion of the carriages as

they took a curve at the foot of a moderate incline, where the rate of speed is admitted to be 30 miles an hour; and although the engineer states "that this curve of a mile radius, or 48,1000th of an inch in 10 feet each way, and taking the curve and incline together, the latter being only 1 in 151," he conceived that a train might travel on it with safety at the rate of 35 or 40 miles an hour; and he therefore did not ascribe the engine and carriages being thrown off the line to the curve, or increased momentum; but in his opinion it was much more likely to have arisen from the irregularity of the rails. Any one who reflects for one moment on the action of the wheels on the rails, when coming down an incline of 1 in 150, at the rate of 30 miles an hour, can, however, be at no loss to account for the accident; more especially if the least defect existed in the shape of the flanch of the engine wheels. Prudence and common sense should however point out that though an incline and curve may often be taken with safety at great speed, still it never can be so without great risk, and it should be imperative at every curve, even of large radii, to slow the engine.

Some engineers put great faith in the adapta-

tion of the wheels of the carriages to suit the curves, and there is no doubt, were the tire of the wheel not arranged for curvilinear railways, the carriages would be constantly liable to be thrown off the lines: but too much reliance ought not to be placed in those contrivances, which have been previously noticed, such as giving a certain degree of elevation to the outer rail, varying with the radius of the curvature, or altering the transverse level, so as to produce upon the carriages a gravitating force towards the centre of the curve, to counteract and be equal to that of the centrifugal force outwards. Tables have been given by M. Pambour and other engineers of the elevations necessary to be given the outside rails, which are greatly contingent on the rate of velocity at which the carriages run: for example, with wheels three feet in diameter, the gauge of rails 4 ft. 8½ in.; play of the wheels between the rails one inch; and the inclinations of the tire equal to $\frac{1}{7}$ of its breadth, or about ½ inch to 3½ inches; a curve nearly one mile radius; speed of carriage 30 miles an hour; the elevation of the outer rail would require to be ·60 parts of an inch, while at 20 miles it would be ·26. Supposing the curve ¾ mile radius, at 30 miles speed, it would be about ·83; at 20

miles ·36; — a curve of $\frac{1}{2}$ mile, at 30 miles, 1·38; and at 20 miles ·59; and 2000 feet, at 30 miles, 1·65; and at 20 miles, ·71; and so on, increasing the elevations of the outer rail as the curve is increased.

Other precautions are made for curves, which are proportioning the degree of the cone of the wheel to them, and inclining the rail that it may receive the wheel fully on its bearing surface, and taking care that the play of axles should be as little as possible, to avoid injuring the effect from the cone. From such provisions as these, to a considerable extent, the danger of taking a curve at a rapid speed is avoided. Without these arrangements the tendency of the wheels would be to drag or press against the outer rail, and from the slight hold they would have when the wheels were going round, the least jerk would upset the carriages or throw them off the rails. By due adjustment of the conical tire and flanch of the wheels, it is supposed that they can run in a circle of 595 feet radius without the flanches touching the rail. No doubt much may be done on curves by accurate adjustment, to adapt the carriages for speed in transit. Fortunately, however, curves of short radius are not now admissible on railways, or it might happen

that the result of theory, instead of practice, might lead to many casualties.

Where double curves exist on railways, as a curve and recurve, the radii should be made in common prudence larger than for a single curve. The curves at the London and Birmingham railway, between Euston Square station and Camden Town, and Kilburn, afford examples of curves of both kinds; on these the radius is not more than is absolutely necessary for safety, and too small for great velocity. In the different railways in this country curves of various radii will be found. The curvature is now very properly made much larger than in the early railways; but still the radius of the curve might be advantageously increased; one mile radius should be the minimum on every railway for locomotive engines.

A few examples of the radius of curvature of railways may be given. On the Ballochney railway the radius of curvature is only 10 chains, and in the Dalkeith and Edinburgh railway the curves are from 600 to 1200 feet, all less than a quarter of a mile, and some not an eighth of a mile; on the Dundee and Newtyle the curves are about 500 feet.

RAILWAYS FOR LOCOMOTIVE ENGINES.

Liverpool and Manchester, least curvature 13 chains.

London and Birmingham, worst curve at Chalk Farm, 600 yards, nearly $\frac{3}{16}$ of a mile radius.

Manchester and Leeds, curvilinear one, 1322 yards, 60 chains, or $\frac{3}{4}$ of a mile.

Birmingham and Gloucester, 1760 yards, 80 chains, or 1 mile.

North Eastern, 1 curve, 51 chains, about $\frac{5}{8}$ of a mile.
another, 100 chains $1\frac{1}{4}$ mile.

North Midland, curve and recurving, 80 chains, or 1 mile.

Lancaster and Preston, 20 chains, $\frac{1}{4}$ mile.

York and North Midland, curvilinear least radius 55 chains, above $\frac{5}{8}$ of a mile.

South Eastern, (Dover) near Reigate, 60 chains, or $\frac{3}{4}$ of a mile.

Edinburgh and Glasgow, 40 chains, $\frac{1}{2}$ mile.

Glasgow and Ayr, nearly 80 chains, 1 mile.

Glasgow and Paisley, 40 chains, $\frac{1}{2}$ mile.

Newcastle and Carlisle, several curves at 20 chains, or a $\frac{1}{4}$ of a mile.

Newcastle and North Shields, 40 chains, $\frac{1}{2}$ mile.

Stockton and Darlington, 20 chains, $\frac{1}{4}$ mile.

Stockton and Hartlepool, 50 chains, $\frac{5}{8}$ mile.

Slamanan railway, 12 curves from 20 to 80 chains, a $\frac{1}{4}$ to 1 mile.

Leeds and Selby, minimum curvature, 40 chains, $\frac{1}{2}$ mile.

Belfast and Portnadown, or Ulster railway, 40 chains, $\frac{1}{2}$ mile.

From the preceding examples it may be observed that no general rule has been adopted in arranging the curvature, but on recent railways few curves of small radius have been made, and in future it is not probable they will be permitted.

From what has been stated, when curves exist on railways, it must be obvious their safety depends entirely upon the proper adjustment of levels of the rails; the rate of speed they are passed over, and the construction of the tire and flanch of the wheel.

FORMATION OF THE ROAD.

Before a railway act can be obtained, by a standing order of Parliament, not merely are the sections of a proposed line required, but detailed plans showing the extent of land to be taken, and the names of the owner, lessee, and occupier of every piece of land likely to be interfered with. The section or profile of the country must show the elevations and depressions distinctly marked from a base line taken from the lowest terminus: vertical lines show the changes of inclination; and straight lines, drawn from point to point, show the line of railway. As the plans and notices of the intention to apply for an act must be deposited some months before the introduction of the bill into Parliament, and also a copy with the clerks of the peace in every county through which the railway passes, and a sum equal

to 10 per cent. of the subscribed capital must be deposited with the accountant-general prior to the presentation of the petition for the bill, there is time for considering the details of the bill; but as the preliminary point of the extent of land cannot be altered without serving fresh notices, the necessity of a thorough knowledge, before the bill is introduced, of the traffic and purposes to which the railway is expected to be generally applicable, must be at once apparent. Nothing more fully proves the necessity of such considerations than to look to the enormous expense which has been entailed on railway companies, not merely for the first bill, but for a succession of amended bills, some railway companies having as many as four or five acts, and almost every company more than one: there were five acts obtained for the Liverpool and Manchester in a few years, 1826, 1827, 1829, 1832, 1837. When an act is contested the expense is well known to be enormous: the first act of the London and Birmingham Railway Company cost 72,000*l.*, and the Great Western 88,000*l.* The London and Brighton cost, with a contest of fifty days, 50,000*l.*

These facts show the necessity of the promoters of railways avoiding crude propositions,

and of fixing on precise data in arranging the undertaking; and nothing is more important, as a preliminary point, than fixing the width of road and extent of land between the fencing, as on this will depend the width of bridges, viaducts, and tunnels, which cannot be altered. Another preliminary point is the operation of levelling,* which requires to be conducted with the utmost accuracy. As on the sections of the levels depend the calculations upon which the estimated cost of the railway is made up, should these be incorrect, the measurement of earth-works, inclination of planes, and total amount, must each be erroneous. Engineers, to avoid mistakes of this kind, are careful in checking the results.

WIDTH BETWEEN THE TWO LINES OF RAILS. SPACES OUTSIDE OF THE RAILS.

The important point of the gauge or width between the rails having been determined for a double line of way—supposing it to be the narrow gauge, 4 feet $8\frac{1}{2}$ inches—the next thing is

* The beautiful instruments now in use have greatly facilitated the taking of levels; and by the reading-off staff a person levelling is enabled to view the heights on the staff at a considerable distance.

to consider the proper space to allow between the two tracks or lines of way. On some of the old railways it was very narrow, and made about the same width as the gauge of the rails—at the Glasgow and Garnkirk, the gauge is 4 feet 6 inches, and the space 4 feet 10 inches. The intermediate space, however, differs much on different lines. The intermediate space on the Liverpool and Manchester railway is 5 feet 8 inches, and on the London and Birmingham railway 6 feet; and experience has shown that this width is not more than is absolutely required for convenience and safety, for several accidents have occurred from articles projecting in one carriage having come in contact with the carriages on the other line.

On the London and Brighton, London and Southampton, the Greenwich, Manchester and Birmingham, Midland Counties, and other railways, the intermediate space is 6 feet 5 inches. On the Edinburgh and Glasgow, and North British, it is 6 feet. On the Leeds and Selby, and the Dublin and Kingston, it is about 7 feet 4 inches. On the Ulster railway, with a medium gauge, it is 6 feet 4 inches; and on the Great Western, with the broad gauge, it is only 6 feet 6 inches. On the Newcastle and Carlisle it is

5 feet $1\frac{1}{2}$ inch; on the Belgian Railways, 6 feet 6 inches.

The proper width of the side spaces on each side of the railway tracks varies in a similar manner, according to the particular views of parties, and from local circumstances. What should be looked to in forming an embankment is the security to give firmness to the blocks and sleepers, and the stability of the rails. Some engineers have stated, and amongst others Mr. N. Wood, that 4 feet outside of the rails, even on high embankments, is sufficient for safety; for the reason, that he considers the general impression is erroneous, that an engine will run over the side of the embankment and drag the carriage after it; whereas, in his opinion, when the engine runs off the rails its speed is immediately diminished; but there being no check to the carriage wheels still upon the rails, their inertia will carry them forward against the engine, pressing it, until the train is stopped. He therefore thinks, that if the width on the outside of the rails be sufficient when one wheel is within the rail to retain the other on the embankment, the train could not run over it.

It must, however, be obvious, that this opinion is hypothetical; for experience has shown a dif-

ferent result. Not only have engines frequently run off the lines drawing carriages after them over embankments, but in general the safety of the carriages has resulted from the breaking of the draw-bar, which connected them with the engine, instead of the result being that the carriages would push forward the engine, which had run off the rails, till it stopped. However much it may be an object to keep down the expense of railway formation, this surely should never be a primary object to public companies, when the safety of thousands is concerned. No point can, therefore, be of more paramount importance than making the spaces outside of the rails of sufficient width to give an embankment stability both in reality and appearance. For nothing can create more well-grounded alarm to the traveller than passing over a high embankment with the carriage running close to the edge, or passing through a deep cutting, or a tunnel, or under a bridge, or over a viaduct, when one side of the carriage is almost touching the walls.

When a railway is curvilinear, as the Newcastle and Carlisle railway, a greater width should likewise be given to the embankment; for an ample space outside of the rails gives a general

aspect of security highly desirable to be adopted on railways where steam is the tractive power.

On the Liverpool and Manchester, the outside spaces are 5 feet 6 inches; on the London and Birmingham and Grand Junction railway, 5 feet at the levels, 3 feet at the stations; and on the London and Croydon and Brighton, 8 feet; which cannot be deemed more than sufficient for any railway using locomotive engines. On the Eastern Counties (Colchester line), the side spaces are 6 feet 9 inches; on the Edinburgh and Glasgow, and Glasgow and Ayr, 7 feet; Dublin and Kingston, 6 feet 7 inches; Belfast and Portnadown, 7 feet 2 inches; North Eastern, 5 feet; Newcastle and Carlisle, 5 feet 3 inches; North British, 7 feet.

On most railways the side spaces average from 5 to 6 feet; but where rapid speed is adopted, 6 or 7 feet is not more than is necessary. These spaces of course vary in width at particular places, such as in passing viaducts, bridges, tunnels, and stations, being diminished about three feet, which is about the width of each of the side spaces on the Greenwich railway.

WIDTH OF THE ROADWAY — THE FORMATION LEVEL.

In the construction of railways the width of the roadway is a point of preliminary arrangement. And difference of opinion naturally enough arises on this as well as on other points of railway practice, although the general mode of formation does not widely differ. From an interesting account given by Dr. Anderson from the communications of Mr. Wilkes, near Loughborough, to the Society of Arts, about 30 years ago, it appears that the manner in which railways were then constructed evinces in all the essential points of earth works a considerable degree of perfection, although at that time horses were the only motive power, and many of the roads only a single line of way.

In a railway as now constructed, the level of the earth works, when completed, is called the formation level (*c d*, *fig.* 45.); it forms the bed in cuttings, levels, and tops of embankments, on which the railway is to be made, and is the point which regulates the other arrangements; for of course it will be made to suit the gauge fixed on, and the other spaces, and is commonly

from 26 to 33 feet, 28 feet being a common width for a narrow gauge line.

For example, the London and Birmingham and Grand Junction railways are between the side cuttings of drains 30 feet, and the width of road at the level of the rails is 26 feet 2 inches; Eastern Counties, width at top of embankments, 30 feet; Birmingham and Gloucester, 28 to 30 feet; London and Brighton, top width of embankments, 33 feet; Liverpool and Manchester, width of way, 25 feet 7 inches; Edinburgh and Glasgow, top width of embankments, 33 feet; width of cuttings from side drain to side drain, 30 feet; North British railway, now making, about the same; Great Western, about 34 feet.

Supposing the measure over each track of rails to be 5 feet 1 inch, being a 4 feet 8½ inch gauge, the two tracks - - -	10 ft. 2 in.
The intermediate space to be - -	6 ft.
And each outside space to be 6 feet - -	12 ft.
The entire width of road at level of the rails will be - - - - -	28 ft. 2 in.
And if this road be carried through a level cutting, width of two slopes, for the thickness of the way, each - - - -	4 ft.
And allowing 1½ feet at each side for drains -	3 ft.
	35 ft. 2 in.

will be the width over the drains between *a* and

b (*fig.* 44.), or should the side spaces be 5 feet each, the width will be 33 feet 2 inches, and the width of the road at the level of the rails, or top of ballasting, 28 feet 2 inches, and 26 feet 2 inches respectively. The figure represents a section of the roadway and drains, showing the rails laid on stone blocks.

Fig. 44.

On embankments there will be 3 feet less for drains, reducing the width (with 6 feet side spaces) to 32 feet 2 inches between *c* and *d* (*fig.* 45.), which

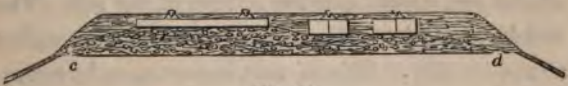


Fig. 45.

is a section of the top of an embankment, showing part of the rails laid with cross sleepers and part on stone blocks: the slope is continued downward according to the height of the embankment.

Sometimes side mounds are raised 2 feet high at the edge of embankments above the road level, as a defence against carriages going over. This plan is not in general use, and their utility is

doubtful in affording effectual resistance against carriages having any momentum. Where these mounds are adopted, the width of the formation level will require to be increased 2 feet on each side, making the width, with 6 feet side spaces, 36 feet 2 inches, where the slope is an angle of 45°, or 1 to 1; or where the slope is $1\frac{1}{2}$ to 1, it will be 38 feet 2 inches.

THE WIDTH OF LAND, AND ANGLE OF SLOPES.

The slopes to be given to cuttings and embankments are regulated in a great measure by their height and depth, and the nature of the soil. The width of land to be enclosed will vary according to the locality. It is of vast importance, however, not to be limited in quantity, and to give easy slopes—every object being directed to the main point of artificial road-making, the attainment of perfect solidity. The quantity of land taken by different railway companies must necessarily vary considerably. On the London and Brighton railway the width of land enclosed is about 72 feet; London and South Western, 69 feet; Bristol and Exeter, 64 feet 6 inches.

It is obvious, however, that in high embank-

ments and in loose cuttings, where considerable slope is required, the extent of land must be much greater than when a railway is made through a flat country, as many of the railways round London are, where the proportion of expense per mile would differ very materially.

It has been the practice in making excavations through sand, gravel, or loose materials, to make the slope one perpendicular to one and a half horizontal; and embankments have been made the same slope, on the supposition that the materials will require the same angle to stand at in both cases.

When excavations are made through solid rocks it is desirable, in order to save expense, to reduce the width of the railway as far as is practicable with safety, and longitudinal drains are cut at the base of the rock to carry off the surface water, and when no incline exists it is pumped off.

The angle of slope of such rock cuttings is, of course, determined by the nature of the strata, whether compact or friable. In the basaltic or whinstone cuttings, on the Edinburgh and Glasgow and Greenock railways, the walls in many places are quite perpendicular. In chalk formation cuttings, on many of the lines in England, the angle of inclination in some is very obtuse;

on others, less so. Chalk will generally stand from nearly vertical to an angle of 45°. In solid chalk the slopes can be effected at $\frac{1}{6}$ to 1, or for 1 yard in height the cutting inclines 6 inches. On the Great Western railway, near Bath, some of the cuttings are perpendicular.

The sand excavations through the Cowran Hills, on the Newcastle and Carlisle railway, are made with a slope of $1\frac{1}{2}$ to 1.

It is the practice on all modern railways to cover the slopes of embankments with a layer of soil, and to sow these with grass, the sod being a preservative to the bank.

In many districts, where stone is plentiful, or where there has been an excess of cutting, as in the Scotch railways, side walls of stone are used as fencing to retain the sides of embankments. The materials used for fencing of railways of course must, in a great measure, be regulated according to the locality. Timber, as being more easily obtained in most parts of England than stone, is almost generally used there for fencing; and in some places ditches are adopted. There is little doubt that no point connected with the safety of railways is more important than a thorough system of secure fencing, to keep cattle from straying upon the rails, so many accidents having arisen from it.

EARTH WORKS.

The enormous earth cuttings and filling up of embankments, which are seen on many of the railways in this country, may well excite astonishment as the works of a few recent years. It is calculated that 16,000,000 cubic yards of material were removed on the London and Birmingham line. The excavation of Mount Olive on the Liverpool and Manchester line, the sides of which are perpendicular, was effected by the removal of 480,000 cubic yards of sandstone rock. The average amount of earth work on some railways has been about 150,000 cubic yards per mile. The depth of cuttings is frequently very great, on some lines from 50 to 70 feet; and a sand excavation on the Newcastle and Carlisle railway is 110 feet deep. The cutting at Blisworth, on the London and Birmingham railway, 50 miles from London, is considered a good example of engineering skill overcoming natural difficulties. The cutting is about 60 feet deep, through strata, the upper portion of which is rock and the lower looser matter. If the slope of the cutting had been extended to overcome the lower strata, it necessarily incurred the labour and expense of

removing the rock above it; instead of which the rock has been underbuilt, and the sides of the cuttings are nearly perpendicular. The same clever plan has been adopted on many other lines. On the same railway, from the Euston station to Camden Town, where a considerable cutting exists, from the nature of the soil, a slope of $1\frac{3}{4}$, or 2 to 1, would have been necessary, taking up much valuable building-ground; to get the better of which, a work of great magnitude is executed — retaining brick walls are built, 3 feet $11\frac{1}{2}$ inches thick at bottom, and 2 feet 7 inches at top. The width between the walls is 56 feet, and they are securely bound with strong iron ties, or beams, extending across the railway, and contre-forts, or piers, are placed at intervals, to sustain the pressure of the soil, varying in height from 19 feet, according to the ground. The face of each wall is curved, the radius being about 60°. The whole length of the wall is about 2200 yards.

The quantity of material which can be removed in cuttings and formations of embankments must necessarily vary with the material: it has, however, been estimated, that about 250,000 cubic yards is the greatest amount which can be teamed over an embankment in one year; but

much will depend on the means employed. The soil is usually deposited in layers, 2 or 3 feet in thickness, slightly concave, in order that one layer may acquire some firmness before another is laid upon it. It is well known that embankments are commonly formed from the excavations; but when soil cannot thus be obtained, side cuttings are had recourse to, and the extent of the *lead* (or the distance the waggons have to go to be filled or emptied) is important, as respects both time and convenience. The formation of embankments and cuttings are therefore carried on simultaneously; and it is of consequence in railway construction, for economy in purchasing land, that these, if possible, should be nearly balanced; otherwise, when a surplus cutting proceeds, a mound of earth, called the spoil bank, must be formed, over which the material is thrown. These banks, if made with an easy slope, may be cultivated. The embankment near the Sanky viaduct, on the Liverpool and Manchester railway, was partly formed of a side cutting. On the same railway the Broad Green embankment, nearly 3 miles in length, measures 135 at base and 60 feet at top in breadth, and is about 30 feet high: the total material laid down was 550,000 cubical

yards. On the Clarence railway, near Durham, some of the highest embankments in the country exist.

The following data shows the immense increase of the bulk of an embankment by augmenting the slopes. An embankment 30 feet high, 66 feet in length, with slopes of $\frac{3}{4}$ to 1, and the top of embankment 33 feet in width, contains 4070 cubic yards; with slopes 1 to 1, 4620 ditto; at $1\frac{1}{2}$ to 1, 5871 ditto; and with slopes, 2 to 1, 6820 ditto.

COATING OF THE RAILWAY.

When the road, if a cutting, has been finished, or if an embankment, consolidated, it is brought to the proper level longitudinally, and also is levelled transversely, or it is made a little convex, about three or four inches, towards the middle, that the water may fall towards the ditches. But as the general material which forms the foundation of the railway consists of earth and clay, it is necessary to cover it with some more open substance, through which the water may penetrate, and the blocks and sleepers may rest on a solid bed and be kept dry; for in some railways the

sleepers have gone to decay, probably from the dampness of the substrata.

The operation of coating the road is effected by overlaying it with what is termed *ballasting*, consisting of a layer of stones broken in small pieces, like road metal. The ballasting varies according to the locality: sometimes it is granite, basalt, or whinstone; at other times sandstone or flint; and gravel is much used in many places, as easily obtained. This coating is spread on the cutting or embankment from 18 to 24 inches in thickness, according to the material of which the road is formed. Smaller sized stones or gravel are laid for the immediate bedding of the blocks and sleepers on their being packed round with any uniting material. The whole line of road is made up near to the level of the rails, or about 3 inches above the tops of the blocks, the thickness being usually, when completed, about two feet from the line of formation of the railway to the surface. The width the ballasting is laid upon the road, will vary with the railway: on some it is made the same width as the top of the embankment; on others it is kept a foot or two narrower. The width of the ballasting on the London and Birmingham, Edinburgh and Glasgow, and North British railways is from 26 to 28 feet, and from

18 to 24 inches in thickness. It is necessary before the line of road is coated, that the entire subsidence of embankments shall have taken place, as any yielding afterwards is necessarily attended not only with danger but inconvenience. It is customary, therefore, in newly-made embankments, in which there is generally a tendency to slip in wet weather, to keep them rather higher than they are ultimately to be; and when the material is unfavourable to give them a considerable slope, the provision required for subsidence shows the imprudence in forcing on embankments with some soils too hurriedly; as the thorough consolidation of the earth of a railway is the only security against casualties, their hasty formation increases their liability to slip. Although the practice is to travel with caution over newly-made embankments, and for the rails to be laid in such a manner as to diminish as much as possible the risk, still from the sinking of the blocks or sleepers, and the constant packing these require, in spite of any precautions, the liabilities to accidents from these causes exist, and show the necessity of circumspection.

When the railway passes through fenny or mossy districts, from the soft and spongy or yielding nature of the soil, the danger increases.

In forming the road through such a locality, the labour and care is tenfold increased; for the surface will often sink under the superincumbent mass, and the ground at the sides be forced up. Much can be effected, indeed, by a proper and judicious system of drainage. The extensive nature of the drainage required in passing through marshy districts has been exemplified on several railroads; and on one line, the Northern and Eastern Counties, the engineer, in order to check the unequal settlement of the embankment, and to bind the earth together, had recourse to inserting a frame-work of timber.

The mode of passing the Chat Moss on the Liverpool and Manchester line as a work of engineering difficulty, requiring much skill, has not been excelled, perhaps, on any other line. The moss, from 10 to 30 feet in depth, is soft and spongy; it extends to about 12 square miles; the railway is carried over it 4½ miles, at some parts under and at others above the level of the moss, so that both embanking and cutting were required through it. As the materials laid down for an embankment about 4 feet high gradually sunk, it became impossible to use either clay or gravel. Recourse was therefore had to the moss itself for the forming of the embank-

ment, which, from its less specific gravity, would not be so liable to sink; and by cutting drains every 5 yards apart, and laying the moss dry between the drains, it formed an excellent material for the embankment, requiring only 4 or 5 times the quantity which would have been used on solid ground. In forming the road on the surface of the moss, drains were first cut on each side of the line and lateral ones to carry off the water, and by this means the surface acquired tenacity and consolidation. Upon this hurdles, 9 feet broad, wickered with heath, were laid transversely; on some parts one, and on others two layers of hurdles were laid. Upon these were placed two feet of ballast or gravel, to form the permanent road, and on which the wooden sleepers for the rails were bedded. Mosses and swamps on other lines of railway have been passed in a similar manner, and sometimes longitudinal sills have been laid along the transverse sleepers.

DRAINAGE.

In general the drainage of a railway on the embankments is sufficiently effected, when a good coating of open ballasting can be obtained. This

will keep the road dry, and the blocks and sleepers effectually free from water. Where a good coating cannot be obtained, or where the width of the road is great, and the least doubt exists as to the consolidation of the road, a different mode of drainage must be adopted, especially in countries exposed to heavy floods of rain. On some railways, surface drains are formed under the middle of each of the transverse timbers, as may be seen on the Great Western. On other lines, as the London and Birmingham, these surface drains are made at intervals, to run transversely across the road, passing under the rails, as may be seen at Primrose Hill. On some places a stone or brick drain, of from 4 to 6 inches square, is carried along the middle of the line, with cross drains at intervals, running from it into the side ditches (*a b, fig.* 44). Sometimes drains are formed on the face of embankments for this purpose. The formation of these drains is a mere matter of engineering arrangement, depending on local circumstances, as material of deposit, or nature of subsoil, and excavations.

On some railways, parallel to the tops of the cuttings, open drains have been made, to prevent the water running down the slopes. Tile drains or wood troughs have been advantageously used

for this purpose. Retaining walls have also been drained with clay pipes, laid obliquely in trenches, opening through the wall, which has tended to their preservation. This plan of drainage has been applied to the retaining walls on the Croydon Railway; they are built in during the work; and also to the walls of the Euston Square incline on the London and Birmingham railway, which was suffering from the lodgment of water and consequent pressure. The wall was bored through in several places, into which holes iron pipes, about 3 inches in diameter in 4 feet lengths, were inserted 16 feet deep. The bank on the same railway, which was in a precarious state from want of drainage, between Chalk Farm bridge and Primrose Hill tunnel, has been successfully drained by means of pipes laid in descending trenches; more than 2600 feet of pipe have been employed.

In surface cuttings and excavations the drainage is very simply managed, when there is any declivity, as shown in *fig.* 44, page 165., when one half of a foot on each side of the formation level will generally be found sufficient, although the exact size of the drain must obviously be regulated by the quantity of water which will be required to be carried away.

RETAINING WALLS.

The immense extent of masonry and brickwork which is required in the erections upon almost every railway necessarily greatly enhances the cost. On some lines, where the road has been formed on the sea coast, or on the side of a steep hill, one side of the embankment has to be supported by a sustaining or revetement wall. These expensive works occur on many railways. An extensive sea-wall of this description has been erected at Granton, on the Edinburgh and Newhaven railway. Similar constructions occur on the Dublin and Kingston Railway, where an embankment at Blackrock is made with culverts, through which the sea passes at high water. On the South-Eastern Railway a strong revetement wall exposed to the sea is carried along the face of the Dover cliffs. On the Preston and Wyre Railway there is an extensive embankment, with a wall to the sea. On the Stockton and Hartlepool Railway an embankment has been formed, made of clay, puddled, and curved to resist the action of the sea. On some railways, in order to lessen the extent which the slope of the embankment requires, strong retaining walls have been

built; or sometimes arches are introduced. The Dublin and Kingston Railway is partly formed in this manner; and it occurs on many lines, as at Linlithgow, on the Edinburgh and Glasgow Railway.

VIADUCTS.

Almost every kind of arching is made use of on railways. The number of arches required on some railways, in the formation of viaducts, bridges, culverts, and drains, exceeds credibility. Viaducts, or roads carried on arches, as is well known, are of ancient origin, being used by the Romans. They are indispensable in railway constructions, in order to cross valleys at a higher elevation than could be done by embankments; likewise for carrying a railway through a town.

The extensive works on railways of this kind are so numerous, that it would take volumes to describe them. In some lines the whole arrangement seems but the choice of, and is attended with, vast and complicated difficulties, which, at first view, it appears almost madness to attempt to overcome; and nothing perhaps but the "esprit de corps," which actuates public companies, could induce them to undertake such works as have been

carried out in this country, where viaducts, tunnels, cuttings, occur in succession, and whole streets of houses have been removed, which might well deter the boldest promoter of railways from embarking in such a scheme. When it is looked to what has been accomplished, one may well feel pride at the spirit which conceived such undertakings, and the engineering talent which carried them to completion. For example — the London and Greenwich Railway passes through a sea of houses, and for nearly four miles is constructed on a continual series of arches, forming one vast viaduct from one end to the other: there are not less than 878 brick arches, chiefly semicircular, 18 feet span, and 20 feet high; but in that number there are 27 skew arches, the principal being over Bermondsey Street and the Surrey Canal. The Blackwall Railway, 3 miles and 843 yards long, is another gigantic work: on it there is a viaduct of 4020 yards, containing 285 arches, chiefly semi-elliptical, of 30 feet span. There is also a viaduct on the Eastern Counties Railway, carried through buildings, consisting of seven semi-elliptical arches, from 33 to 36 feet span. Works of a similar description occur in towns upon other railways: an extensive series of stone arches is now making to carry a railway through the middle of the city of Glas-

gow. Viaducts over rivers and valleys occur on almost every railway of any extent. The Warncliffe viaduct over the valley of the Brent, at Hanwell, on the Great Western Railway, is a beautiful work, consisting of 8 semi-elliptical arches, 70 feet span. The Sankey viaduct, on the Liverpool and Manchester line, contains nine arches of 50 feet span and 67 feet in height above the canal; and on the same railway the Newton viaduct has 4 arches of 30 feet span. The Lawley Street viaduct, on the Grand Junction, at the Birmingham station, is also an extensive work, consisting of 28 segmental arches, 30 feet high and $30\frac{1}{2}$ feet span. On the Manchester and Birmingham Railway there is a fine work, the Stockport viaduct, 2179 feet in length, over the Mersey, 106 feet high, consisting of 22 semi-elliptical arches, each 63 feet span, 28 feet 6 inches between the parapets. On the Manchester and Leeds Railway there are 5 viaducts; one in the Manchester terminal plane of 54 arches, from 12 to 30 feet span. The Wakefield viaduct consists of 11 arches, 30 feet span, and one less. On the Midland Counties, the Avon viaduct near Rugby consists of 11 semi-elliptical arches, of 50 feet span. There is a viaduct on the Chester and Birkenhead Railway of 11 arches; and on the

Chester and Crewe Railway, the Ellesmere canal is carried by an aqueduct over the railway. On the Edinburgh and Glasgow line two extensive viaducts occur. The Almond viaduct is supported on 36 segmental arches of freestone, of 75 feet span, and the versed sine 16 feet 6 inches. The width between the parapets is 26 feet, extreme width 28 feet 6 inches, and height above the river 50 feet. The Avon viaduct has 20 arches. Timber has been occasionally used in this country for economy, for forming short viaducts, on the plan introduced in America; but, from their elasticity and vibration, they are not considered advantageous for the rapid speed of locomotion. A fine viaduct of this kind, supported on columns, has lately been made at Croydon, for the Atmospheric Railway. A viaduct of this description is now making on the North British Railway, near Edinburgh. Messrs. J. and B. Green, C. E., adopted arched timber viaducts on the Newcastle and North Shields Railway, chiefly on the ground of less cost. They designed a plan in 1833, which was put into execution in 1837, of timber arches resting upon stone piers, at the Ouse Burn viaduct. There are five arches, the versed sine 33 feet, and the radius 68 feet: three of them are 116 feet

span each, and two of them 114 feet each. Each arch is composed of three ribs, and cast-iron imbedded in the masonry to receive them.

BRIDGES.

The bridges formed on railways in this country are so numerous, that their bare enumeration would be impossible. It has been estimated that the number of bridges, taking the mean of 100 railways, averaged about 2¼ per mile. On one railway, the Grand Junction, 82 miles, there are 106 bridges over and 63 under the railway.

On the Manchester and Leeds Railway, 60 miles, there are 116 bridges, besides viaducts; Midland Counties, in 48 miles, 148 bridges; North Midland, 73 miles, 133 bridges; North of England, 45 miles, 84 over and under; Liverpool and Manchester, 30 miles, 55 over and under.

On the Edinburgh and Glasgow Railway, in 46 miles there are 31 bridges over, and 31 under, the railway, of 15 feet span, besides the viaducts.

On the Glasgow and Greenock line, in 21 miles there are 60 bridges and culverts, including the Port-Glasgow viaduct.

Sometimes the arches are made entirely of brick. They are so on most of the English lines.

The arches on the London and South-Western line are chiefly of brick, 28 feet in span and 16 feet in height. On the Scotch railways the bridges are built almost entirely with stone. Iron is occasionally used in place of brick and stone. Cast iron girders or ribs are in common use, laid from one abutment to another. Six ribs are made to support the four rails and two parapet walls, having nothing upon the girders except a platform of iron plates, flag-stones, or planking. By this plan the depth of the bridge can be reduced, strength is obtained, and no ballasting is required.

Bridges are also occasionally made of timber of a similar construction; but they want the appearance of durability, being better adapted for temporary erections. Messrs. Green constructed an extensive structure of timber over the river Esk at Dalkeith, for the Duke of Buccleuch's coal works.

Skew, or oblique arched-bridges, have been much introduced in railways when the line has to intersect any road or other place at an oblique angle. As it is most important in railway formation to avoid angles and keep by a straight line, a skew bridge becomes a great convenience, from the circumstance that the railway over the bridge, and the road under it, may be made to form unequal

angles with each other. The construction of these arches requires very great skill, both on the part of the engineer and executor of the work. On the Liverpool and Manchester Railway the arch near Rainhill is 54 feet on the skew, and the angle of obliquity 34°.

The skew arch at Bermondsey Street on the Greenwich Railway, consists of three openings; one for carriages, 17 feet 6 inches wide and 19 feet high, and two for foot-passengers, 6 feet 6 inches wide. The whole is effected at an angle of 38°, and is constructed of six cast-iron ribs extending over the three arches 58 feet in length: they are supported on twelve cast-iron columns 16 feet in height.

The bridge over the Dog Row, on the Eastern Counties Railway, is a skew one; span 55 feet; made of cast iron, with longitudinal and transverse girders. The larger girders are 3 feet in depth, 2 inches thick, with an upper and lower web, each 9 inches wide, and run from one abutment to the other.

On the Great Western Railway, at Maidenhead, there is a bridge of ten semi-elliptical arches of 128 feet span, having the rise or versed sine only 24 feet 3 inches. There are also some very handsome iron bridges at Bath.

On the Manchester and Liverpool Railway there is a bridge over the Irwell at Manchester, 65 feet span; and on the same line, the Saint Helen's Railway is carried over the former by means of a handsome iron bridge with cast-iron columns.

On the South Western Railway some of the bridges are made with cast-iron girders covered with stone; but it has been found difficult to keep the joints tight.

On the North Union Railway the bridge at Preston over the river Weaver, built of stone, consists of five semi-elliptical arches, 140 feet span.

On the Manchester and Bolton, where little height existed between the rails and the road over it, the two lines have been separated by iron columns, to allow the utmost height for the carriages.

On the London and Birmingham there are some elegant bridges; the one carrying the Edgeware Road over the railway is made of iron springing plates, with intermediate arches of brick built in cement. The one at Rugby is constructed of cast iron. There are seven bridges on this line from Euston Square to Camden Town. The iron-tie bridge over the Regent's Canal at Camden Town is a fine work.

A considerable difficulty often arises in forming bridges over railways, from the desire of keeping down the arch for the same roadway over it; hence many very flat arches are to be met with, which weaken the bridge, and often give it a very insufficient aspect, which ought to be avoided.

The bridges now in the course of construction on many of the lines of railway now carrying on in this country, will not be inferior, as works of skill and enterprise, to those that have preceded them. The proposed passing of the Menai Straits on the Chester and Holyhead Railway has already called forth great engineering skill.

When railways were first introduced, they were improperly allowed to cross turnpike roads on a level. On those railways, accordingly, for which Acts were passed previously to 1836, these objectionable crossings are very common; as on the Stockton and Darlington, Newcastle and Carlisle, Liverpool and Manchester, Dublin and Kingston, Glasgow and Garnkirk. Great danger from such level road crossings must obviously arise where steam power is employed, from vehicles passing when the train is at rapid speed, or from cattle straying on the rails. These crossings are properly now prohibited. Indeed, it seems much

more for the advantage of the railway company to build a bridge to ensure permanent safety, than to erect a lodge and gates, with a man constantly stationed on the spot.

TUNNELS.

Tunnels are the most formidable and expensive of all the works on a railway, and the cost of them being contingent on the nature of the ground to pass, unseen obstacles often intervene to increase the expense. Tunnels are great drawbacks to the comfort of railway travelling; and being objectionable in every point of view, the skill of the engineer is fully displayed in avoiding them. Accordingly, in most of the recently designed railways they are avoided as much as possible. It is, however, quite impossible in many localities to dispense with them altogether, without perhaps having recourse to as great, if not greater evils. They may, therefore, be called necessary evils in the present state of railway formation. To attain proper gradients, few lines of railway of any extent can be constructed without having recourse to these laborious and tedious formations.

Tunnelling, or the art of cutting subterranean

passages through the bowels of the earth, has been long practised; and extensive tunnels have been constructed, through which several of the canals of this country have been carried. Tunnels are constructed either by perforating the earth by means of horizontal shafts entering them from the face of a hill, or by sinking vertical shafts as a pit would be sunk. When tunnels have to be carried through granite or solid basalt, or whinstone, or compact sandstone rocks, the labour and time occupied must be very great, as nearly the whole operation is carried on by blasting. In the Scottish railways several laborious works of this kind have been effected. On all tunnels of any length ventilating shafts must be provided; for although it does not appear that tunnels have been attended with those bad consequences to health at first apprehended, still immunity from personal injury will not make them more bearable or less offensive. Their safety and exemption from annoyance will therefore depend entirely on having air shafts at short distances; and above all things giving them, at whatever cost of first outlay, sufficient elevation. The height of the tunnel is of importance when locomotives pass through it; for even when coke is consumed the smell is most offensive; but should coal be used

for the engine, the tunnel will be rendered much more disagreeable.

The height of the tunnels used on railways varies, like most points connected with them, exceedingly. In general, to save expense, they are kept too low; nor does there appear any fixed rule to go by, judging from the tunnels in existence. The distances apart, likewise, of the ventilating shafts, and the diameter of these, vary in a similar manner.

A few examples may be referred to, by way of illustration.

On the London and Birmingham line there are several tunnels; the principal of which are, Primrose Hill, Kilsby, Kensall Green, Watford, Weedon, and Birkswell.

Primrose Hill tunnel, 3750 feet long, 22 feet high, 22 feet wide, is carried through plastic clay. The brick-work is 18 inches in thickness, built in cement. There are five ventilating air-shafts about 9 feet in diameter; they are raised about 8 feet above the ground. These shafts were used, in making the tunnel, for lowering the materials and raising the excavations.

The Kilsby tunnel is about 6600 feet in length. Its excavation was a difficult work, from the tunnel passing through strata in part of running sand. It is 27 feet high and $23\frac{1}{2}$ wide.

The Watford tunnel is 1 mile and 39 yards, or 5397 feet: it is carried through chalk. About the middle there are two large shafts for ventilation.

The Kensall Green tunnel is a quarter of a mile in length.

The Box tunnel on the Great Western Railway, on the incline 1 in 100, between Bath and Chippenham, is fully $1\frac{3}{4}$ mile, (9372 feet) in length. It is 27 feet 6 inches in width at springing of invert: above this line it is 30 feet. The clear height above the rails is 25 feet. The air-shafts are 11 in number, generally about 25 feet in diameter.

On the Liverpool and Manchester Railway there are three tunnels. The first, from Wapping station to Edge Hill, is 6600 feet in length, 22 feet wide, and 16 feet high. The side walls are 5 feet perpendicular, for supporting the semicircular arch of brick. Some parts of the roof are formed by natural rock. This tunnel was executed by means of vertical shafts. The passenger tunnel, from Edge Hill to the original station in Crown Street, is 870 feet in length, 15 feet wide, and 12 feet high. The tunnel descending to the station in Lime Street is about 5280 feet (one mile) in length, 25 feet in width, and 19 feet in

height. At the Western entrance the segmental arch rises 12½ feet.

On the Manchester and Leeds Railway there are eight tunnels, one of which is 8580 feet, or 1 mile 5 furlongs in length. It is 23 feet wide at springing of invert, 24 feet at springing line of arch of roof, and the height from spring of invert to the soffite of arch is 21 feet 6 inches.

On the South Eastern (London and Dover) there are several extensive tunnels: the Shakspeare tunnel at Dover has a double bore, or a tunnel for each line of way, 12 feet wide. It is made in the form of a Gothic arch, 19 feet to the spring of, and 30 feet to the top of, the arch. The Chalk Cliff Tunnel is 4290 feet in length, on an incline of one in 284: it has seven audits or galleries. The Abbot's Cliff tunnel is 6609 feet long, 24 feet wide, and 25 feet high: it has vertical shafts and galleries.

On the Manchester and Bolton Railway there is a tunnel of 900 feet.

On the Leeds and Selby there is a tunnel 2100 feet in length, 17 feet high, and 22 feet wide, and there are three shafts for ventilation.

There is a tunnel 300 feet on the Whitby and Pickering line, 14 feet high, 10 feet wide; the side walls are upright for 9 feet, and support an

arch of 18 inches brickwork. The entrance to the tunnel is built in a castellated form.

There is a tunnel on the Leicester and Swannington Railway, about 5280 feet, or a mile in length, 10 feet 8 inches wide at the base, and 11 feet 9 inches at the springing of the semicircular arch; the height is 13 feet 6 inches. There are four ventilating shafts 3 feet in diameter, raised 8 feet high above the ground. There is a tunnel on the Chester and Birkenhead Railway 573 yards long, and 16 feet high.

On the Newcastle and Carlisle Railway, 60 miles in length, there is only one short tunnel.

On the Edinburgh and Glasgow, in the opposite extreme, in the short distance of 46 miles, there are five tunnels, some of which are long, cut through solid rocks. The Falkirk tunnel, on a curve, is 2490 feet in length; the Winchburgh, 990 feet; and three tunnels together at an incline at Glasgow, 1328 feet, 876 feet, and 816 feet respectively. The height of these tunnels is 26 feet, and the width 22 feet. On the Ayr and Greenock Railway there are short tunnels cut through the solid rocks. On the Edinburgh and Newhaven a tunnel 3000 feet in length is now making under part of Edinburgh. It is 24 feet wide, and 17 feet high. This has been a most

difficult and laborious work, chiefly arising from the looseness of the strata, consisting of sand, shale, basalt, and freestone: the deepest vertical cutting will be 90 feet. Another tunnel of considerable extent has also been made at that city, on the North British Railway. It is cut through the basaltic rock of the Calton Hill. The whole of this tunnel has been lined with brick-work — a very complete, although expensive, undertaking; the width of this tunnel is about 24 feet, and the height about 17 feet.

One of the first railway tunnels made in the same neighbourhood was that on the Edinburgh and Dalkeith railway, opened in 1830. It is 1710 feet long, placed on a steep incline. It is a semicircular span of 20 feet.

RAILWAY STATIONS.

The labours of railway formation may be concluded with a short notice of railway stations.

The position of railway stations upon a line, and the number of them, is a matter entirely contingent on local circumstances. As a general rule it may be kept in view, that the greater the number and convenience of the stations, and the

cheaper the fares, the greater is the probability that the traffic on the line will increase. The size and accommodation of the station houses vary from the humble office of one apartment to those splendid establishments some of which are observed on almost every railway; such as the stations at Euston Square and at Rugby, on the London and Birmingham Railway; those at Bristol, Bath, Slough, and Swindon, on the Great Western; also the stations at Liverpool, Manchester, Birmingham, York, Derby, Glasgow, &c.

The architectural design and plans of these it is not purposed to describe: many of the station buildings display considerable architectural taste, others a paucity of it. It might be well when railway depôts and stations form so conspicuous objects, that pure classic designs were adopted, and premiums might most advantageously be awarded for competition designs. Iron roofs are much used for railway stations: they require most careful construction. Too much attention cannot be bestowed on the arrangements at the stations, as much of the convenience, comfort, and safety of passengers depend on them. As a general rule, the plan has been adopted of having all stations and depôts on a level with the railway, wherever it is possible: this prevents incon-

venience in many respects to passengers, and also in the transfer of goods. The position of the engine houses, coke stores, goods' warehouses, &c., are also points in the arrangement of railways which, both as respects the guarding against accidents and for convenience, display skill on the part of the engineer. There is not one point connected with railways that requires more speedy correction than the dangerous practice of passengers being obliged to cross the rails to get at the up-trains. This improper practice exists on almost every railway at out-stations, and the numerous accidents which have occurred from it might long ere this have pointed out the necessity of its abolition. There are few travellers but know the danger of scrambling over rows of iron rails in the dark, to get at the landing platform on the opposite side of the railway, where the train they want is to stop. A fatal accident which occurred at the Falkirk station on the Edinburgh and Glasgow Railway, by a gentleman crossing the line to get to the carriage, being run down by a coming-in train, very promptly led to a bridge being thrown across the rails, and so preventing the necessity of the passengers walking in future on the rails at all at that station: and why should not this plan be obligatory on railway companies through-

out the kingdom; as also that they should land passengers at all times on a platform? I have seen passengers at some stations landed in the dark amid the rails of the line, and where cross lines meet, and obliged to find their way to the platform in the best manner they could. By a little attention to the arrangement of the stations and landing-places, and the manner of attaching and detaching of luggage waggons, carriage and cattle trucks to and from trains, many accidents may be prevented, or casualties guarded against.

COST OF RAILWAYS.

Thus have been gone over some of the important works connected with the formation of railways; from the preceding descriptions some idea may be formed of the multifarious details. From these works may be perceived the enormous expense attending forming the line of way, and the necessity of (while the railway is designed with all due regard to economy) its utility not being injured by ill-judged parsimony. It must be indeed obvious that the cost of railways is much, if not altogether, contingent on local circumstances; and in estimating the future returns from a rail-

way, the cost per mile must be the most important consideration; in general, railways have been constructed and arranged more on the principle of convenience, and in the hope of such an increase of traffic arising as would repay the first vast outlay on them; while others, again, have been, by fortunate adventitious circumstances, formed at a very cheap rate. The cost of the London and Birmingham Railway was about 52,882*l.* per mile; the Grand Junction, 22,293*l.*; Liverpool and Manchester, about 50,923*l.*; Great Western, about 56,372*l.*; London and Brighton, about 56,981*l.*; London and Greenwich, 267,270*l.*; London and South Western, about 28,004*l.*; London, and Blackwall, 287,693*l.*; London and Croydon, 80,400*l.*; Birmingham and Gloucester, 29,000*l.*; Manchester and Leeds, 47,824*l.*; Midland Counties, 35,402*l.*; York and North Midland, 23,066*l.*; Dublin and Kingston, 59,122*l.*; Edinburgh and Glasgow, 35,024*l.*; Glasgow and Greenock, 35,451*l.*; Glasgow, Kilmarnock, and Ayr, 20,607*l.*; North Union, and Bolton and Preston, 27,799*l.*; Dublin and Drogheda, 15,652*l.*; Dundee and Arbroath, 8,570*l.* per mile.

MOTIVE POWER OF THE RAILWAY.

THE subject of railways has been viewed hitherto chiefly in regard to the roadway on which the carriages have to run. The consideration which next presents itself is the mode of working the railway, and the motive power best adapted for this purpose, both in respect to safety and economy. Railways indeed would have made slow progress in this or any other country — nor would they have been at all likely to supersede canals and other modes of conveyance — had the old plan of working them by horses, or stationary engines, still continued. Confined as these agents were to a slow rate of motion, and ill adapted for general traffic, however convenient for local purposes, there could have been no stimulus to extend the expensive works which have been described connected with railway formation, håd it not been for the invention of a motive power which brought a new principle into action, unknown in former times, combining economy of working with the

utmost velocity. The rapid advancement of railways in these times is clearly attributable to one thing. In many questions doubts may arise as to success being attained by a combination of circumstances; but never was any thing more clearly defined or brought out, than that railways owe their present success and prosperity to the invention and perfecting of the *locomotive engine;* and although it may yet happen, by the strange anomalies of events, that, after all the labour and time spent, and skill displayed, in bringing this machine to the perfection it has attained, it may perhaps be doomed, after a precocious maturity and short usage, to be superseded by another mode of propulsion,—the atmospheric or some other scheme, which may lead again to the use of fixed engines; still it must be interesting to trace the progress and history of an invention which has already proved of vast utility to mankind.

INVENTION OF THE LOCOMOTIVE ENGINE.

For many years the locomotive engine had been retarded by an erroneous and imaginary assumption, which prevailed since the general introduction of iron rails, that there was not

sufficient friction between the face of a smooth wheel and rail to produce adhesion, or resistance enough to cause the wheel to move onward, instead of simply turning on its axle,—which is technically called *skidding* of the wheels. It seems to have been supposed, that from this taking place, and want of sufficient gripe or bite, not only there would be loss of power, but the advance of the carriage would be retarded. Strange as it may now appear, futile schemes were proposed and much money was expended on contrivances to get rid of this supposed difficulty, when the solution of the point could have been attained by a few experiments. This shows the necessity of testing inventions by experiment and experience — these may be truly termed the only safe basis upon which practical improvement can be raised.

In looking back on the short history of railways, we cannot but wonder that so little progress was at first made with steam power. The steam engine cannot boast of great antiquity; for although the ancients knew something of steam, they knew nothing of motive power or mechanical applications. The invention of the steam engine is generally ascribed to the Marquis of Worcester in the year 1663; but to Savary, who obtained a patent for his steam engine in 1692,

Newcomen, Watt, and others, is fairly due the merit of the invention of the steam engine, as the Marquis of Worcester's projects were wild and fanciful. There were many difficulties to overcome before the steam engine could be made applicable to purposes of locomotion. No doubt the double-acting steam engine had, in the year 1782, been brought by the genius of Watt to such a degree of perfection as to admit of few subsequent improvements; but how unsuitable such an engine must be, with its heavy frame work, huge fly wheel, its beam, condenser, and cumbrous boiler, for locomotive purposes. Had these clever adaptations for stationary steam engines not been got rid of, the locomotive engine would have made little advancement. Who can doubt that repeated trials and experiments must have been made ere the least excellence could have been attained in the application of the steam engine as the *motar* on railways.

It must have been obvious to engineers, almost from the first, that locomotive engines must be differently constructed from the common condensing engine. From the period of Watt till within the last 30 or 40 years high-pressure engines were rarely used in this country: indeed a strong prejudice existed against them from ap-

prehension of their safety. These prejudices gradually wore out where small steam engines were used: and when steam power came into use — from 15 to 20 years ago — in Scotland for farm purposes, high pressure or noncondensing engines, on the reciprocating principle, were generally preferred, from cheapness, as the motive power for barn machinery. Engines of this description are now in general use at farms in Scotland and the borders of England.* The usual pressure at which these high-pressure engines are worked is from 30 to 35 lbs. on the square inch; and no accident with them has yet occurred at farms, showing that with good management there is perfect safety.

TREVITHICK AND VIVIAN'S LOCOMOTIVE ENGINE.

Steam engines, however, modelled after the form of condensing engines, were obviously very unsuitable for portable or locomotive purposes. The first high-pressure engine, it is generally admitted, applicable for the latter purpose, was the invention of Richard Trevithick and Andrew

* The author has now in the press a work, for which a premium was awarded, on the application of the steam engine to farm purposes.

Vivian, engineers, of Camborne, in Cornwall. In the specification of the patent, dated March 24. 1802, it is described "for improving the construc-
" tion of steam engines and the application thereof
" for driving carriages on rails, and turnpike roads,
" and other purposes;" likewise, that their engine will produce a "more equable rotatory motion on
" the several parts of the revolutions of any axis
" which is moved by the steam engine, by causing
" the piston rods of two cylinders to work on the
" said axis by means of cranks at ¼ turn asunder."

It is also mentioned that they occasionally propose
" to make the external periphery of the wheels of
" carriages uneven by projecting heads of nails, or
" bolts, or cross grooves, or fittings to rail-rods,
" and that in cases of a hard pull to cause a lever
" bolt or claw to project through the rims of one
" or both wheels, so as to take hold of the ground;
" but that in general the ordinary structure of the
" external surface of the wheels would be suffi-
" cient; that the form of the engine might be
" varied by changing the relative velocity of rota-
" tion of the wheels as compared with that of the
" axis by shifting the gear, or by having toothed
" wheels of different sizes; the body of the carriage
" to be made of any convenient form according to
" its use." In this clever invention the steam was proposed to be worked either at high pressure or not.

If the former, at a pressure from 60 to 80 lbs. on the square inch, and the boiler was made of a cylindrical form, to bear the expansive action of strong steam, having a bent tube like the letter U within it, to increase the heating surface. The furnace was placed within the boiler, as in the common marine boiler; and they proposed occasionally to excite the fire by bellows, worked by the piston, or crank of the engine, or by any plan found convenient. The cylinder of the engine was likewise immersed in the boiler. To guard against explosion a second safety valve was provided, not under the control of the engineer — a plan which subsequently has been universally adopted in locomotive engine boilers, and which arrangement should be applied to steam boilers of every description.

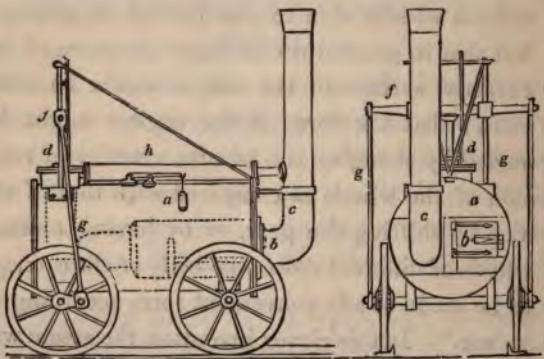


Fig. 46.

Fig. 46. is a side and end elevation; *a* is the boiler, with flat ends, the fire being contained within the tube *b*, entirely surrounded with water; *d* the steam cylinder, placed nearly to the bottom of the boiler — the waste steam passes into chimney *c* by eduction pipe *e*: the piston rod is attached to cross-head *ff*, which slides in vertical guides, from the ends of which the connecting rods *gg* descend to the cranks on the axles of the fore wheels, and makes them revolve: *h* is the safety valve of the boiler.

In the year 1804 the inventors constructed an engine for moving railway carriages. This was the *first steam engine* applied to locomotive purposes in Britain. It was used successfully on the railroad at Merthyr Tydvil, in South Wales. The cylinder was placed horizontally, as in locomotives now used. The heads of the piston rod and connecting rod were divided, or forked, leaving room for the motion of the extremity of the crank, and giving motion to it fixed on an axle-tree: on this axle cog-wheels were placed, working into cog-wheels on the axle of the hind wheels. This locomotive engine, which in many of the leading features was essentially the same as those now in use, had only one cylinder

of 8 inches diameter, and a stroke of 4 feet 6 inches, with a fly-wheel to regulate the action of the crank. At its first trial it drew as many carriages as carried ten tons of bar-iron a distance of nine miles, travelling at the rate of five miles per hour. It is doing mere justice to these inventors to state that, to them belongs the merit of having first applied the steam engine successfully to the purposes of locomotion; and that those who reaped the subsequent harvest merely did so from the seed they had sown.

Although Messrs. Trevithick and Vivian had thus, to a certainty, so far succeeded in making use of the steam engine as the motive power for railway carriages — still the action of their locomotive was confined to the level plane, which destroyed much of its efficiency, and the erroneous belief entertained, to which I have already alluded, of the want of bite, or adhesion of the wheel to the rail, rendered the progress of locomotive traction, in a great measure, nugatory; accordingly, for nearly 25 years subsequent to their patent, very little was done to advance the object, although, no doubt, numerous attempts were made, and some of these were, perhaps, unheard of.

BLENKENSOP'S LOCOMOTIVE, AND RACK-RAIL.

The next patent for this object was that granted to Mr. John Blenkensop, of Middleton Colliery, near Leeds, in 1811, for what he termed a rack-rail, adapted for carriages.

In the specification of his patent he mentions that he proposed to fix upon the ground, or road, over which a conveyance is to be made, "a "toothed rack, or a longitudinal piece of cast "iron or other material, having protuberances, or "other parts, of the nature of teeth, standing "upwards or downwards, or sideways, or in any "required position; and that the toothed rack "should be prolonged by fixing to it other pieces "so far as required upon the road;" that he proposed "to fix, apply, and connect, with a carriage "for the conveyance of goods or passengers, a "wheel having teeth or protuberances, or other "parts of the same nature as the teeth belonging "to the longitudinal rack; and when the carriage "was suitably placed on the road the wheel was to "revolve and drive its carriage along by the appli-"cation of any such well known power or first "mover as can be placed upon and carried along "with the carriage." He also declares that a steam

engine is greatly to be preferred to any other first mover; and, further, that he proposed to connect it by a crank, assisted by a fly-wheel, or by other well known methods of connection, and to make the connections either directly with the arbor of the said wheel, or indirectly by another wheel, where the one crank or other driving force cannot with convenience be fixed upon the arbor of the wheel. And, further, to render the motion of the carriage more easy, he proposed, as might be most convenient, to avail himself of contrivances heretofore in use, and that a preference should be given in every instance to an iron railway, upon which the toothed or common wheels of his carriages should run; and in that case he connected his longitudinal rack with the railroad itself — as one of the sides forming the railroad might be cast with teeth, so that it would constitute the toothed rack itself, and, at the same time, afford a regular and even bearing for the wheels, and for the toothed wheel, which, if its plane were vertical, may be made with a side-run to bear upon the smooth part of the rail, and prevent the teeth from locking too deep; and, lastly, to give motion to other carriages by attaching the same to the carriage upon which the first mover was

placed; and that these other carriages were fitted up without, or did not require the toothed wheel. And he also, when preferred, made use of two toothed wheels acting upon corresponding racks at each side of the rails: fig. 47.

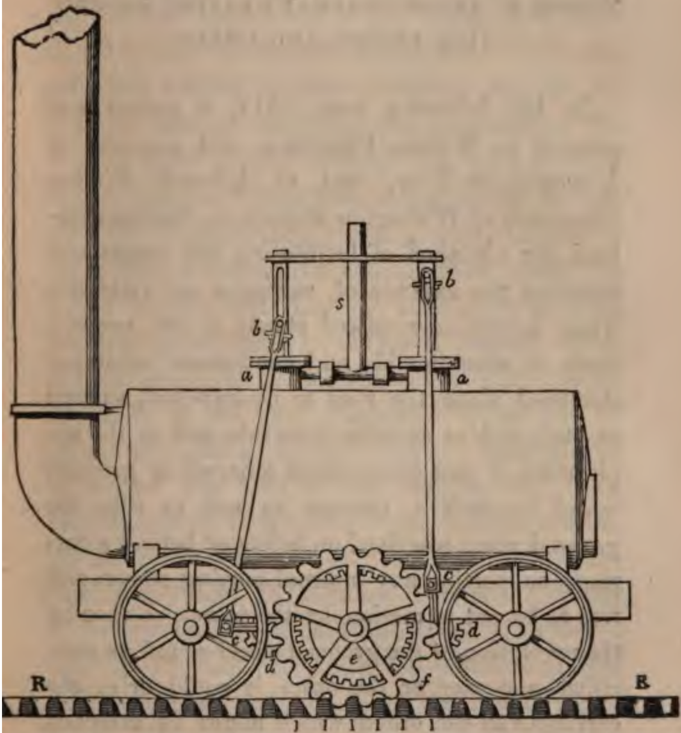


Fig. 47.

This complicated and extravagant scheme seems to have received the most careful consideration, and much time must have been spent in perfecting the details: but the idea was soon abandoned.

MESSRS. W. AND E. CHAPMAN'S PATENT LOCOMOTIVE ENGINE AND CHAIN.

In the following year, 1812, a patent was granted to William Chapman, civil engineer of Newcastle-on-Tyne, and to Edward Walton Chapman, of Willington Ropery, in Northumberland, for a method of facilitating the means and reducing the expense of carriages on railroads. Their invention consisted chiefly in the use of a chain or other flexible and continuous substance stretched along the road to be travelled, secured at each end at suitable intervals, and in the application of this chain round a barrel or grooved wheel in such a manner as not to slip, the grooved wheel was fixed on before or behind a carriage, supporting any internal moving power, and was to be put in motion by the power, so that by the revolution of the grooved wheel round its axis, either one way or the other, it could drive the carriage and the others which might be attached

to it. The patentees stated that it was already known that self-acting locomotive engines had been made for the purpose of drawing carriages after them; but the object of their patent was not to include in their invention what had heretofore been publicly done, but simply to claim such a position and application of the things they mentioned as fell within their description. "That the principal feature in their invention was the advantage that no alteration was required on the waggon ways or rails, whether they were of wood or iron, because if they were strong enough to sustain coal waggons they would be amply capable of supporting a locomotive engine when placed on 6 or 8 wheels, and thus the alternative hitherto laboured under would be obviated; namely, either that of the weight of the engine destroying numerous rails, or the total renovation of the way by laying new rails at a great charge." This plan of an engine was tried at the waggon way, from Hetton colliery to the river Tyne, near Newcastle. By this plan carriages using the chains could not pass each other: the method, therefore, required two railways, one in each direction. The weakness of the rails laid down for railways at this period forming an obstacle to the use of heavy engines, may account for the proposal of Messrs.

Chapman of placing the weight of the engine upon two frames supported by 6 or 8 wheels; still the cumbrous action of 8 wheels and such a length of framing must have made such a moving power most unwieldy.

BRUNTON'S PATENT LOCOMOTIVE, WITH LEGS.

The next invention emanated from Mr. William Brunton, engineer of the Butterly ironworks in the county of Derby, who, in the year 1813, took out a patent for a singular contrivance to overcome the ideal obstacle of the want of sufficient adhesion of the wheels of carriages. The specification of his patent describes a method and machinery "for propelling or drawing carriages "upon roads or railways by means of certain levers "or legs alternately or conjointly acting upon such, "or upon machinery attached thereto." He proposed to propel the carriage by steam power, by one, two, or more legs (*a b*, *d e*,) *fig.* 48., page 215., acting against a rope chain or rail, and which legs are attached to or connected with the moving power in such a manner as to receive from it a reciprocating motion, by the levers (*a c*, *d c*,) something similar to the motion of a man's legs when in the act of

walking, which motion might be communicated by any of the usual and fit mechanical means employed

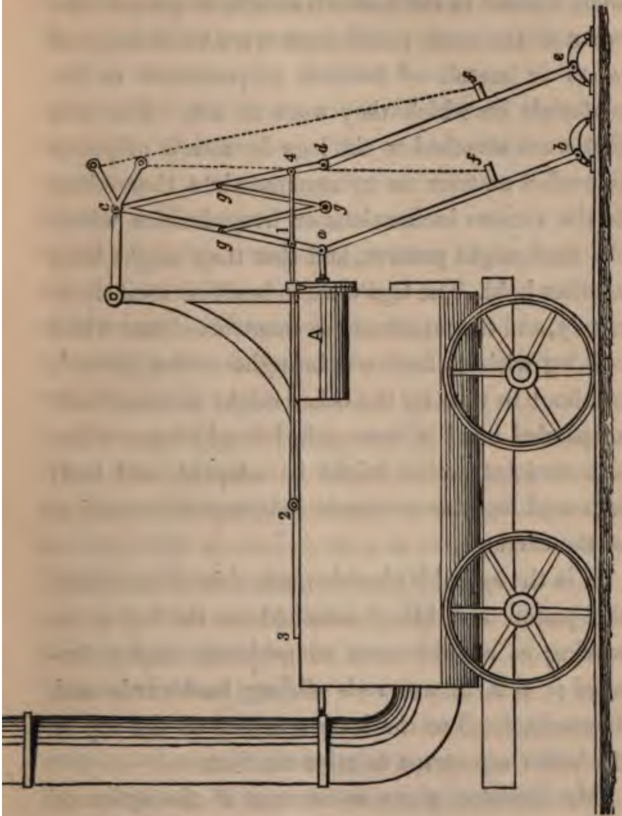


Fig. 48.

by machinists. The lower extremities of the said

levers or legs were to be furnished with one or two other pieces, which he called *feet* (*b e*), with *shoes* formed to the best advantage, to prevent the wear of the roads; and these were to be made of wood or metal, of breadth proportioned to the materials on which they were to act. The said feet were attached to the legs by means of joints in such a manner as to accommodate themselves to the various inclinations or irregularities which the road might present, and that they might keep a better hold. The legs were to be either used alternately, and the machinery so constructed that when one leg with its foot was brought to the ground, or about to take it, the other might be raised and suspended until it was again brought into action, or a conjoint action might be adopted, and both legs used together to obtain the progressive motion of the carriage.

A is the cylinder placed on one side of the boiler, the piston rod being attached to the leg at *a*, serving as an abutment to push the engine forward; 1, 2, 3, are rods sliding backwards and forwards, fixed to the lever *a c*, *d c*; on the top of the boiler are straps to raise the feet.

Mr. Brunton gives an account of the action of his engine, which he terms the "mechanical tra-

veller," in the "Repertory of Arts," from which it appears that his propelling legs were tried upon a railway at the Crick Lime Works, belonging to the Butterly company, and he states that they performed very well. He first ascertained that the power necessary to move it at the rate of 2½ miles an hour, was 84 lbs. The machine there tried consisted of a steam engine, having a cylinder of 6 inches diameter, and 24 inches stroke (the whole weight, including water, being about 45 cwt.), with steam equal to 40 or 45 lbs. on the square inch. The machine was propelled at the rate of 2½ miles an hour, and raised perpendicularly 812 lbs. at the same speed, — making the whole power equal to 896 lbs. at 2½ miles an hour. This, he observes, is nearly equal to the power of six horses; but, as the machine was working on a railway with an incline of 1 in 36, he calculated that it performed the work of 4 horses, and for which it was amply powerful. He also remarked that, with respect to the advantage of this machine, and the various purposes to which it was applicable, much might be said; that it was a most simple and easy substitute for horses, particularly for conveying heavy materials on railways, or even waggons on turnpike roads.

Such is a description, as given by the inventor, and it is singular to observe so much ingenuity and mechanical skill displayed in trying to perfect so complicated and extravagant a machine.

TINDALL AND BOTTOMLY'S PLAN.

The next account of an invention for reducing the expense of carriage on railways and other roads, emanated from Messrs. William Tindall and John Bottomly of Scarborough, in the form of a communication to the Society of Arts, dated June 4. 1814. They proposed that a rotatory motion should be given to wheels of carriages fixed to the axles by means of an endless chain passing over toothed wheels and grooved pulleys fixed on some convenient part of the axle of the wheels, and under and nearly round a toothed pulley turned by the power of the engine, which carriages were to be kept at proper or suitable distances by means of bars of iron, which served as joints. The chain was composed of circular and oval links placed alternately; the pulleys were toothed to suit the circular links; the indentations by which the teeth are produced being nearly

semicircular. Intermediate pulleys were to be used, chiefly to press down the chains on the larger portions of the circumference of the other pulleys, or the axles of the wheels, which might, without inconvenience, be made of various sizes. The slack chain was hung over pulleys fastened to the arbor of the intermediate pulleys, but loose pulleys sufficed. They proposed a break to be used for descending planes.

SLOW PROGRESS OF INVENTION.

The absurdity of such propositions may now appear extraordinary; but those who know the difficulties which so often practically exist in making experiments, and the great outlay these involve, will be inclined to make every allowance for practical men, and it should induce those having the power and means to aid in trying, and not discouraging ingenious suggestions. By doing so, many years, perhaps, in the progress of useful improvements might be gained. The inventive genius of mankind does not appear to have advanced by hasty strides. Knowledge seems not to have been attained in the progress

of years, but rather that of centuries. The refinements of science and the achievements of art seem to have been gained like the slow gatherings of the gleaner. Successful invention, however, in some instances may be compared to a ray of light bursting on the tunnel's darkness; — how beautiful and distinct is the object when revealed! When the mystery is gone and the enigma is solved, how many then can lay hold of and successfully follow out the suggestion, heedless of those who, with blighted hopes, have laboured at it in vain!

BLACKET'S EXPERIMENTS.

About the year 1814 it became known that the progressive motion of the carriage neither required racks nor chains, to which, it appears, the failure of Trevithick's engine had been imputed. This fact, so essential in the science of locomotion, was proved by experiment on the Wylam railroad, for which Mr. Blacket of Wylam had an engine made in 1813, on Mr. Trevithick's plan, working on a plate rail, the friction of which would aid the experiment. He found that the adhesion on it was sufficient in ordinary gra-

dients to make the wheels move onwards dragging a load of considerable weight. Mr. Blacket afterwards improved his engines and ascertained the quantity of adhesion. It is surprising how it should have been so long before this was ascertained. It is probable the error originated in the want of sufficient weight in the carriages experimented with; for of course it is now known that the adhesion or bite of the wheel is regulated by the pressure, and in proportion to the weight resting on the smooth surface, and to the extent of the surfaces in contact, or, in general terms, it may be said, that the bite of the wheel on the iron rail depends much on the weight of the carriage.

STEPHENSON'S KILLINGWORTH LOCOMOTIVE.

The next locomotive engine was constructed about this period by Mr. George Stephenson, at Killingworth colliery, and was tried on the railroad there in 1814. It was considered a great improvement on the previous one. It was found to drag eight loaded carriages, about 30 tons, at the rate of four miles an hour. It had two vertical cylinders, each of 8 inches diameter, and two feet stroke placed at each end of and

within a cylindrical boiler, having a tube of 20 inches passing through it. Two pair of wheels were worked with cranks placed at right angles, which were retained in their position by means of an endless chain passing round two cogged wheels.

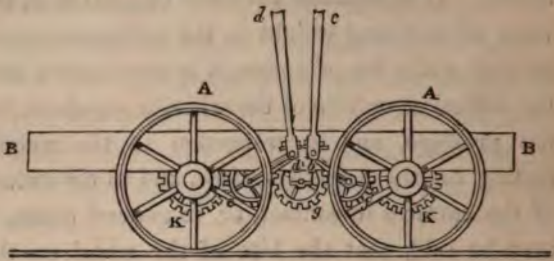


Fig. 49.

Fig. 49. shows the mode by which motion was communicated to the carriage wheels; A A, are the wheels; B B, the carriage frame; *a*, *b*, *c*, *d*, connecting rods, giving the motion from the piston to the cranks, which turn the two cog-wheels, *e*, *f*; these again turn the two larger cog-wheels KK fixed in the axles, and move the carriage wheels.

This plan of connecting the wheels was soon found inconvenient; and to obviate the defects, Mr. G. Stephenson and a Mr. J. Dodd took out a patent in 1815 for a method of communicating the power to the engine without those cog-wheels. One plan proposed was the application of a pin

upon one of the spokes of the engine wheels; the connecting rod fixed to the cross beam of the engine, and moving with the piston, being attached, at the lower end, to the spoke of the wheel, and working in a ball and socket joint. The reciprocating motion of the piston was thus

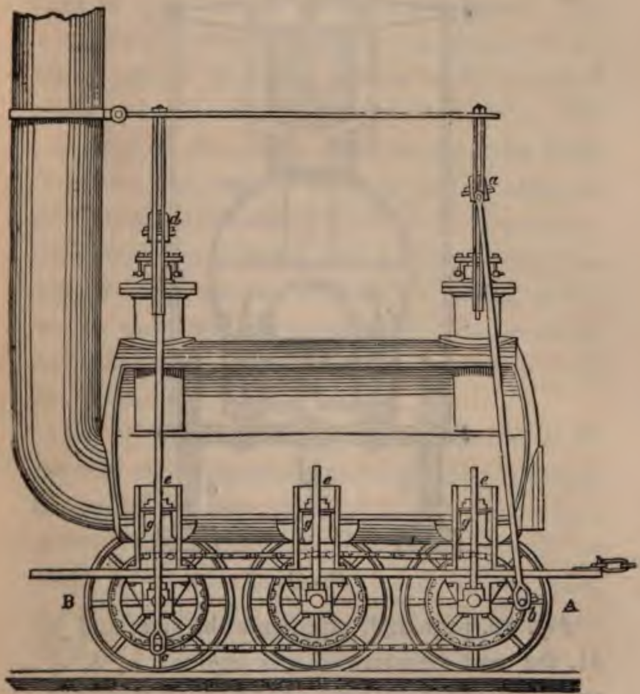


Fig. 50

converted, by the pin acting as a crank, into a rotatory motion.

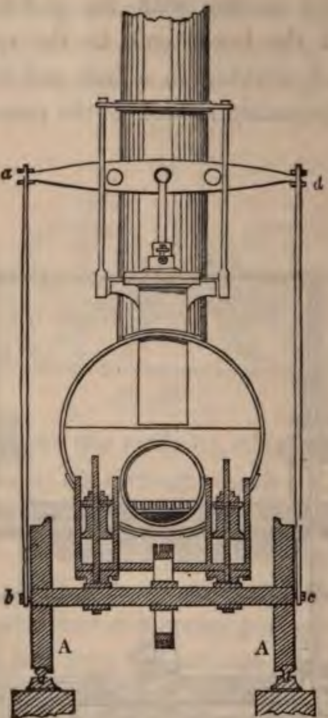


Fig. 51.

Fig. 50. page 223. represents the side, and *fig.* 51. the end elevation of this engine; *a, b, c, a* are the connecting rods, attached at their lower

ends, *b*, *c*, to the pin fixed on the spokes of the wheels A B.

To keep the cranks at right angles with each other, the patentees used a kind of endless chain, consisting of one broad and two narrow links, which lay upon or passed over a toothed wheel, fixed to each axle, as shown in the figure. The principle of action of this was very similar to the plan proposed of giving motion to the wheels of carriages by Messrs. Tindall and Bottomly. The periphery of the wheels fixed on the axles being furnished with cogs or teeth, projecting about an inch, these teeth entered between the two narrow links, and had a broad link between every two cogs, resting on the rim of the wheel, which caused the chain to move round with the wheel, and prevented one wheel being moved without the other.

Mr. G. Stephenson may be considered to be the first who successfully used locomotive engines. It has, indeed, been stated that he had remarked, in 1814, that if the wheels of carriages could be made to have sufficient adhesion on the rails, there was no limit to the speed such an engine could go at, provided the works could be made to bear the action. This opinion has, indeed, been corroborated by the events of subsequent years;

but the locomotive engine had a long course of probation to undergo before it reached any degree of perfection.

LOSH AND STEPHENSON'S PATENT.

The next attempt at improvement on it which Mr. Stephenson made was part of Messrs. Losh and Stephenson's patent in 1816. The improvement they aimed at is distinctly stated in the specification of their patent to be, "*sustaining* the weight, or a proportion of the weight of the engine upon *pistons*, movable within the cylinders, into which the steam or water of the boiler is allowed to enter, in order to press upon such pistons, and which pistons are, by the intervention of certain levers and connecting rods, or by any other effective contrivance, made to bear upon the axles of the wheels of the carriage upon which the engine rests."

Fig. 50. page 223. *e e e* show the cylinders placed within the boiler, one side being supposed removed to expose them to view: *g g g* are solid pistons, fitting the interior of the cylinders, and packed in the usual way. The cylinders are open at the bottom, and were screwed upon the frame of the

engine. The piston was furnished with an inverted rod, the lower end of which passed through a hole in the frame, and supported the engine, and pressed upon the chair which rested on the axis of the wheels upon which the carriage moved. The chair had motion up and down with the piston rod. The pressure of the steam upon the piston transmitted the weight to the axle, and the reaction took an equal weight from the engine. Supposing the area of the cylinders and pressure on the piston to be equal to the weight of the engine, the latter would be supported, as it were, by the steam, thus making the steam serve the purpose of an elastic spring. When four wheels were used the weight was equally divided upon them; but when six wheels were used, as shown in the figure, only one frame was required for the carriage, which simplified the construction. This invention, like many others, aimed at too much, was too complicated, and not sufficiently precise to be of much use.

STEAM POWER ON TURNPIKE ROADS.

Notwithstanding the efforts which had been made in constructing locomotive engines, still, in the years 1814 and 1815 travelling by the *chemin de fer* seemed a long way off. About this period, and extending over several years, the idea seems to have been prevalent that steam power could be advantageously applied to moving carriages on turnpike roads, and consequently much skill and capital were spent in the next to fruitless attempt to bring these inventions into successful operation. It is interesting to observe how much progress had been made in this branch of locomotion. The subject has been so fully treated on by others, that a simple glance at it will suffice. Several years ago an opinion favourable to the rotatory principle of the steam engine invented by the Earl of Dundonald for steam carriages was entertained; and although this has not yet realised the expectations, nevertheless, according to trials made at Portsmouth dock-yard by Mr. Taplin, considerable success has attended the experimental use of the rotatory engine for stationary purposes, although it has not yet been sufficiently tested otherwise.

It appears that the idea of constructing a steam carriage adapted for turnpike roads was long entertained by various persons; among others, by James Watt, in 1769, to whom almost every suggestion as to the application of steam power seems to have occurred. Watt, in the history of his own improvements, states, that in 1759 the idea originated with the late Professor Robison, then a student at Glasgow, of using steam power for locomotion. The idea to use steam for this purpose also occurred to Evans in America. Mr. Trevithick, in 1802, was the first, however, who tried, in Britain, to construct a steam carriage suitable for a turnpike road. Mr. Griffiths tried it in 1821, and Mr. David Gordon in 1824. Messrs. J. and S. Seaward, Messrs. Hill and Burstall, Mr. Hancock, Mr. J. S. Russell, and others likewise, tried it; but of all the projectors none seems to have been so successful as Mr. Goldsworthy Gurney. He obtained a patent for his steam carriage in 1827, and in 1829 had brought it to such perfection that he was enabled to ascend with it the highest hills round London, and travelled from London to Bath and back. In 1831 one of his steam carriages ran about four months on the road between Gloucester and Cheltenham.

The obstructions which Mr. Gurney met with in using his carriage on turnpike roads induced him to petition Parliament, and a committee of inquiry was appointed. Much evidence was adduced, which is only now so far interesting as marking an epoch in the science of locomotive travelling. The purport of the opinion of the committee in 1831, strange as it may now seem, was favourable to steam carriages on public roads, reporting on the practicability of working such with saving to the public, great increase of speed, and perfect safety.

The success of Mr. Gurney's steam carriage led to the formation, in Scotland, about this period (1834), of a steam carriage company for turnpike roads. The carriages commenced to ply regularly between Glasgow and Paisley, when an unfortunate accident occurred, in 1835, attended with considerable loss of life from the explosion of one of the steam boilers, which made this attempt to introduce steam carriages on public oads as abortive as other attempts had proved.

PROGRESS OF THE SCIENCE OF LOCOMOTIVE ENGINES IN 1825.

But a new era was about to dawn on the science of locomotion. Railways, till that great work, the Liverpool and Manchester Railway, was undertaken, were chiefly, as has been noticed, of a local character, and not applied to supersede the ordinary conveyances. Perhaps the first great scheme of railway transition was proposed in 1823, namely, a railway from London to Edinburgh, and all the manufacturing towns. A pamphlet of the scheme was published, without the author's name, in London, 1823, entitled "Observations on a General Iron Railway for improving the internal Communication of these Kingdoms, and forming a Railway from London to Edinburgh, passing near or having branches to all the principal Towns."

In 1825, Mr. Wood gives the standard of the performance of a locomotive engine, at that time, as 40 tons, moved at the rate of 6 miles an hour upon a horizontal edge railroad.

He stated, assuming 150 lb. as the amount of a horse's power, he will draw 10 tons on a railway

with the same ease that he could draw 27 cwt. on a common road, travelling 2½ miles an hour, while a locomotive could drag, going at 6 miles an hour, 45 tons, exclusive of carriages. Mr. Wood also stated, in 1825, "that nothing could do more harm towards the adoption of railroads than the promulgation of such nonsense as that we shall see locomotive engines travelling at the rate of 12. 16. 18. and 20 miles per hour."

It may be thus seen that the locomotive engine had not made great advancement, at that date, from the period when Mr. Stephenson and Mr. Dodd had taken out their patent in 1815. Still, the main obstacle having been removed, and the principle of adhesion understood, sufficient data had been obtained: — thus, on a machine of 5 tons weight, on four wheels, the adhesion was found equal to 5 cwt., and the amount of power being ascertained necessary to overcome the adhesion of the wheels to the rails when the wheels were fixed to the axle, few obstacles, therefore, existed to the progressive improvement of locomotives. Accordingly, Mr. Stephenson gradually improved on his plan, and upon the Hagger Leases Lane branch of the Stockton and Darlington Railway he had an opportunity of testing, on a large scale, the effect of locomotive

engines, which have since acquired such extraordinary powers of velocity. The system was first brought to the test on this railway, which was opened on the 17th of September, 1825. The Stockton and Darlington Railway was the first public railway, perhaps, in the world, where this powerful mode of transit was carried successfully into effect. But, about this period (1824), the Hetton Colliery Railway was likewise worked by steam power.

ENGINE, AS LONG USED UPON THE KILLINGWORTH RAILROAD.

The following is a description of an engine which was long in use at Killingworth Colliery Railroad, and which continued to be used, without material alteration, till the year 1829, which affords the means of judging of the actual state of advancement which the locomotive system had attained at that period. *Fig.* 52. represents a side, and *fig.* 53. an end, elevation.

The boiler of the engine was made of malleable iron, cylindrical, with hemispherical ends; having a cylindrical tube passing through it within 2 inches of the bottom. In one end of this tube the fire grate was placed, and at the other end

the chimney. The boiler rested upon a square frame, supported by springs (*a a*), two on each

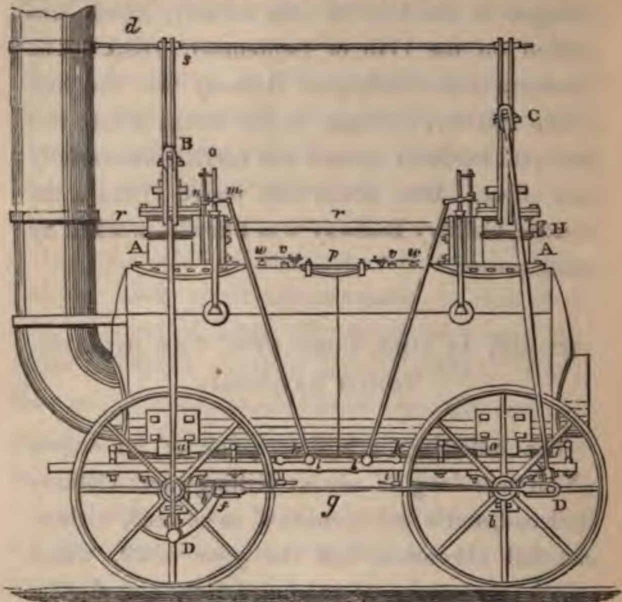


Fig. 52.

side. The chairs on which the axles rested were made to slide up and down within the guides (*b b*), and the action of the springs was communicated to them by a pin passing through a hole in the frame of the engine, one end of the pin resting on the back of the spring, and the other end on the upper side of the chair or bearing. The wheels were thus made to yield to the inequality

of the road. The cylinders were placed vertically, and partly within the boiler at A A. The piston

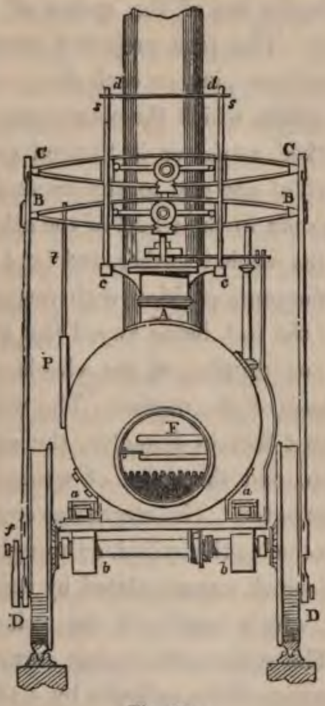


Fig. 53.

rods were attached to the cross beams B B, C C. The rectilinear motion of the piston rod was preserved by the slides (*s s s s*) fixed to the projecting arms (*c c*), and kept perpendicular by the braces (*d d*). The connecting rods (B C, C D) were

attached to the cross beams by ball and socket joints, and at the other end by similar joints to a pin fixed upon one of the spokes of the engine wheel (D D). The pins projected outwards, and upon one of these pins, on each side, a crank (D *f*) was fixed, within which the connecting rod of the pistons worked, as shown in the end view. A rod (*f g* D) fixed at one end to the crank and at the other to the pin in the wheel of the other cylinder connected the whole together, and kept the pistons always in the same position with respect to each other; and the rod, being keyed fast at each end, prevented any slipping of the wheels without the whole partook of the motion. The wheels of the engine were 4 feet in diameter, the spokes made of cast iron, and the axles of wrought iron, $3\frac{1}{2}$ inches in diameter. The steam was communicated from the boiler to the cylinder through a passage, the area of which was regulated by a sliding lever, or handle, which regulated the velocity of the engine. The steam, after being admitted to the top and bottom of the cylinder by a sliding valve, escaped by the pipe (*r r*) into the chimney. The slide valve was opened and shut by an eccentric, connected to the lever *f g h*, communicating motion to the arm *i k*, through it to the lever *k l*, to the rod *l m*, to the cross head *m n*, and so to the rod *n o*, of the sliding valve.

The boiler was supplied with water by a force pump P, which was fixed to the side of the boiler, and worked by a rod *t*. *p* is the man-hole door to get access to the boiler; *v* is the safety valve, with the weight *w* to regulate the pressure.

The performance of this engine in 1829, weighing with the tender (the carriage which accompanies a locomotive engine with the supply of water and fuel), about 10 tons, was equal to convey 10 tons at the rate of six miles an hour, the evaporating power being equal to 15 gall. of water per hour.

Notwithstanding the work which the locomotive engines at this period could perform, fixed engines were generally preferred, and many powerful engines were in use for working inclines, as has previously been pointed out at the colliery railroads in England and Scotland. It is necessary to keep this in view, as it may tend to explain the report which was given in upon the Liverpool and Manchester Railway; for, although the importance of locomotive engines was gradually becoming to be more estimated, still the knowledge respecting them was very limited and confined within a narrow range; and they were generally considered at that time as less efficient as a prime mover than fixed steam engines.

PROJECTION OF THE LIVERPOOL AND MANCHESTER RAILWAY.

The greatest railway which had been undertaken in this country up to this period was the Liverpool and Manchester. The idea of its formation most unquestionably originated four years previous to the act being obtained in 1826, with the late Mr. William James, to whom the railway system of this country is so much indebted, while he himself reaped little or no benefit from his valuable suggestions.* To him likewise is due the projection of the London and Birmingham railway. Mr. James had witnessed the operations of the locomotive engine around Newcastle on Tyne, and communicated his sentiments on the subject to Mr. Saunders of Liverpool, and impressed him so much with the feasibility of applying this plan of railway traction, that Mr. Saunders, to whom the honour of being father of the undertaking has been given, had a survey made of the line at his own expense.

The Liverpool and Manchester Railway, at first met with considerable opposition in par-

* A subscription has lately been got up in England for a tribute to the memory of Mr. James.

liament. It was resolved, July 1825, that Messrs. G. and J. Rennie should be the engineers. Messrs. Rennie, from some cause or other, retired, and Mr. George Stephenson, who had been appointed resident, 20th of May, 1824, was elected principal engineer, 29th of May, 1826. At that period, and during the progression of the work, and as it drew towards completion, both the directors and the engineers turned their attention to the moving power to work it: but so little, however, was really known, either as to the capabilities of railways, or the most advantageous mode of working them, that when the line was proposed, the transport of heavy goods was considered to be the chief source of revenue of the line: neither was the prime mover to work it fully decided upon till it was nearly completed; demonstrating, beyond a doubt, how little was really known of the power or advantages of locomotive engines. That horse power was not suitable for an extensive traffic with considerable velocity, was admitted; and, although the Stockton and Darlington line had done much to show the capabilities of locomotive power, it became a question of some difficulty for the directors to decide on the comparative merits of locomotive and fixed engines. Different opinions were of

course given to the directors on the rather perplexing point of the motive power. One of the first decided opinions that I have met with, on the mode of working the line, emanated from Mr. C. Sylvester, C. E., in a Report on Railways and Locomotive Engines, addressed to the Committee of the Liverpool and Manchester projected Railroad, dated November, 1824, and published in Liverpool in 1825. Mr. Sylvester had made an examination of the engines at Killingworth and Hetton collieries, the latter being one of the first railways where steam power was adopted, and found "that a locomotive could move up a plane, a little more than an eighth of an inch to a yard; but beyond that the wheels turned and made no progress:" but he stated that the advantages of a railroad on which locomotive power was used were so striking, that it was a matter of surprise to him this mode of conveyance had not been resorted to earlier. "The adoption, however, was now inevitable, and when applied in proper places and under judicious management, it could not fail of becoming highly beneficial to the public." He recommended the locomotive steam engine as the most economical power for every part of a railway in which the rise is not more than one tenth of an inch to the yard; and

stated that, in examining the Liverpool and Manchester intended line, he found the greatest rise, and that only in one instance, to be not more than one twenty-third part of an inch to the mile. Mr. Sylvester also states, that "since commencing my report, the principles I have laid down have been given in a newspaper called the 'Scotsman,' in which the author speaks of it as a new idea, at least as applied to railways, although it is founded on facts long ago given by Coulomb and Vince. Whatever may be the claim to originality, in this application, I have at least an equal claim to originality with that author, as my Introduction, which developes these principles, was read by several of my friends before the above article was made public."

The communication to which Mr. Sylvester refers in the "Scotsman," were certain papers on Railways written by Mr. C. Maclaren, editor of that paper, and published in December 1824. In these articles Mr. Maclaren brought forward and supported the views of Coulomb and Vince, with respect to friction and volition, namely, that the friction is the same for all velocities, which had been overlooked by other writers; and that it followed, from this law — subtracting the resistance of the air — that if a car were set in motion on

a level railway, with a constant force, greater in any degree than was required to overcome the friction, it would proceed with a motion continually accelerated; and that it is only the resistance of the air, increased as the square of the velocity, that prevents this indefinite acceleration. The papers of Mr. Maclaren display much ability; and, at a time when so little was really known of any other impelling agent for railways than the draught of horses. Mr. Sylvester's views were, however, founded on practical observations; and the very decided manner in which he gives his opinion in favour of locomotive engines, when so much dubiety existed about an invention which has since awaken mankind from comparative torpidity to active volition, shows that he had formed a correct estimation of its utility.

Mr. Sylvester's able report probably had some influence on the Board of Directors of the Liverpool and Manchester Railway; for we find three years afterwards, October 1828, a deputation of the directors visited the different railways where steam power was used, as the Hetton, Darlington, and Newcastle Railways, for the purpose of obtaining information: and Mr. Booth states in his pamphlet that several of the directors became favourable to the adopting the locomotive power

of traction. At length, when the railway drew towards completion, Messrs. Walker and Rastrick, engineers, were engaged by the company to visit the various local railways, and to obtain practical information respecting the comparative effects of stationary and locomotive engines. The reports of these engineers were published separately at the time, March 1829; but they both concurred in opinion that fixed engines were preferable to locomotive ones, and accordingly recommended their adoption. They proposed the fixed engines to be placed at intervals of a mile or two along the line of railway, and to draw the trains by means of ropes from station to station.

Mr. George Stephenson, the company's engineer, and Mr. Joseph Locke, were also requested to report on the subject of the motive power. The purport of their report was, that Mr. G. Stephenson was decidedly, as he had uniformly been, in favour of locomotive engines, which he was confident would be found the most convenient power that could be employed, and it is stated that when he was examined before a Committee of the House of Commons, in 1828, his claim to credibility was almost doubted when he spoke of locomotive engines going at a greater speed than 10 miles an hour.

EXPERIMENTS — LIVERPOOL AND MANCHESTER RAILWAY.

The Directors of the Liverpool and Manchester Railway eventually resolved to adopt the locomotive principle of traction; and the idea originated with Mr. Harrison, one of the directors, to offer a premium for the best engine which could fulfil certain conditions. The directors, therefore, on the 25th of April, 1829, offered the sum of 500*l.* The chief stipulations were —

1. That the engine must "effectually consume its own smoke," according to the provision of the Railway Act, 7 Geo. IV.

2. The engine, if it weighs six tons, must be capable of drawing after it, day by day, on a well constructed railway, on a level plane, a train of carriages of the gross weight of twenty tons, including the tender and water-tank, at the rate of ten miles an hour, with a pressure of steam on the boiler not exceeding 50 lb. per square inch.

3. There must be two safety valves, one of which must be completely out of the control of the engine man, and neither of which must be fastened down when the engine is working.

4. The engine and boiler must be supported on springs, and rest on six wheels, and the height from the ground to the top of the chimney must not exceed 15 feet.

5. The weight of the engine, with its complement of water, must not exceed six tons, and a machine of less weight will be preferred if it draw after it a proportionate weight;

and if the weight of the engine, &c. do not exceed five tons, then the gross weight to be drawn need not exceed fifteen tons, provided that the engine, &c. shall still be on six wheels, unless the weight be reduced to four and a half tons or under, in which case the boiler, &c. may be placed on four wheels. And the company should be at liberty to put the boiler, the fire-tube, cylinders, &c. to test at a pressure not exceeding 150 lbs. per square inch, &c.

6. There must be a mercurial guage affixed to the machine, with index rod, showing the steam pressure above 45 lbs. to the square inch.

7. The engine to be delivered, complete for trial, at the Liverpool end of the railway, not later than the 1st of October, 1829.

8. The price of the engine which may be accepted not to exceed £550, delivered on the railway.

N.B. The railway company will provide the engine tender with a supply of water and fuel for the experiment. The distance within the rails is 4 feet 8½ inches.

Such was the proposal which led the way to those important improvements which the locomotive engine has attained. The conditions seem to have been drawn up with as much consideration as the imperfect knowledge of the subject, at that time, permitted. But the main point brought out was — that engines, for such a purpose, must possess lightness, compactness, and perfect safety with speed. The condition of fixing as the minimum 10 miles an hour, evinces how little was really known of the capabilities of the locomotive powers of traction, still it did not preclude the

competitors from trying their skill in increasing the velocity.

The stimulus of a premium had the effect anticipated in obtaining a competition, for several able manufacturing engineers turned their attention to the subject, which led to the development of the principle upon which a moveable engine should be constructed to be successful.

The 6th of October, 1829, was the day fixed for the trial; and the directors, to assist their own judgment in coming to an impartial decision on the merits of the engines which might be produced, appointed as judges, Mr. J. W. Rastrick of Stourbridge, Mr. Kennedy of Manchester, and Mr. Nicolas Wood, C. E., of Killingworth.

In order still further to ascertain the comparative merits of the competing engines, to subject them to a practical test, and to point out the mode in which the experiments were to be conducted, the judges drew up the following (among other) regulations: —

1. That the weight of each locomotive, with its full complement of water in the boiler, should be ascertained at the weighing of the engine at 8 o'clock in the morning on the day of trial, and the load assigned to it shall be *three times* the *weight thereof*. The water in the boiler shall be cold, and there shall be no fuel in the fire-place. As much fuel shall be weighed and as much water shall be measured and

delivered into the tender-carriage as the owner of the engine may consider sufficient for the supply of the engine for a journey of $32\frac{1}{2}$ miles. The fire in the boiler shall then be lighted, and the quantity of fuel consumed for getting up the steam shall be determined and the time noted.

2. That the tender-carriage, with the fuel and water, shall be considered to be, and taken as part of the load assigned to the engine; those engines carrying their own fuel and water shall be allowed a proportionate deduction from their load according to the weight of the engine.

3. The engine and carriages attached to it shall be run by hand up to the starting-post, and so soon as the steam is got up to 50 lbs. per square inch, the engine shall start upon its journey.

4. The distance the engine shall perform each trip shall be one mile and three quarters each way, including one-eighth of a mile at each end for getting up the speed and for stopping the train. By this means the engine, with its load, will travel one and a half mile each way at full speed.

5. Each engine shall make ten trips, which shall be equal to a journey of thirty-five miles, which shall be performed at full speed, and the average rate of travelling shall not be less than ten miles per hour. As soon as the engine has performed this task — which will be equal to the travelling from Liverpool to Manchester — there shall be delivered to her a fresh supply of fuel and water, when she shall go up to the starting-post and make other ten trips — which will be equal to the journey from Manchester back to Liverpool.

6. The time of performing each trip shall be accurately noted, as well as the time in getting ready to start on the second journey; and should the engine not be enabled to take with it sufficient fuel and water for a journey of ten trips, the time occupied in taking in a fresh supply shall be considered as part of the time performing the journey.

In accordance with these regulations, and some additional ones by the directors, the engines were to be in readiness at ten o'clock on Tuesday, the 6th of October, 1829. The running ground was a part of the railway on the Manchester side of Rainhill Bridge, and no person but the directors was to be permitted to enter or cross the railroad.

The ground fixed on at Rainhill was a level piece of road, about two miles in length, and about ten miles from Liverpool, on the top of the Whiston and Sutton inclined planes, between Hayton Lane and St. Helen's junction.

On the day appointed, four engines entered for the prize: —

The Rocket -	Mr. Robert Stephenson.
The Novelty -	Messrs. Braithwaite and Erickson.
The Sans Pareil -	Mr. T. Hackworth.
The Perseverance	Mr. T. Burstall.

One of these engines, the Perseverance, having met with an accident in its conveyance to Liverpool, was withdrawn at the commencement of the experiments, so that the contest lay between the three first.

After preparing the engines for the contest, and exhibiting their powers to the company assembled, the judges then came to the deter-

mination that each engine should be tried on different days, the ground being marked off. An eighth part of a mile at each end of it was allotted for starting and stopping, and, on the intermediate level space of a mile and a half, the engine was to proceed at its full speed, and the rate of velocity was to be ascertained by one of the judges being stationed at each end of the ground to mark the time taken in traversing and reaching the extremities, the engine dragging the train the one way, and pushing it before it the other.

EXPERIMENTS WITH THE ROCKET ENGINE.

The Rocket being first ready, was first put on trial. It weighed as follows: —

	tons.	cwt.	qrs.	lbs.
Engine, with a supply of water in the boiler,	4	5	0	0
Tender, with water and coke, - - -	3	4	0	0
Two carriages, loaded with stones, - -	9	10	3	26
Total weight when set in motion -	17	0	0	0

Fig. 54. represents a side view of the engine and end view of the boiler. A is the boiler, with flat ends, 6 feet long, 3 feet 4 inches diameter; at one end of it is the fire-box B, which is double, as shown in cross section. The size of the fire-

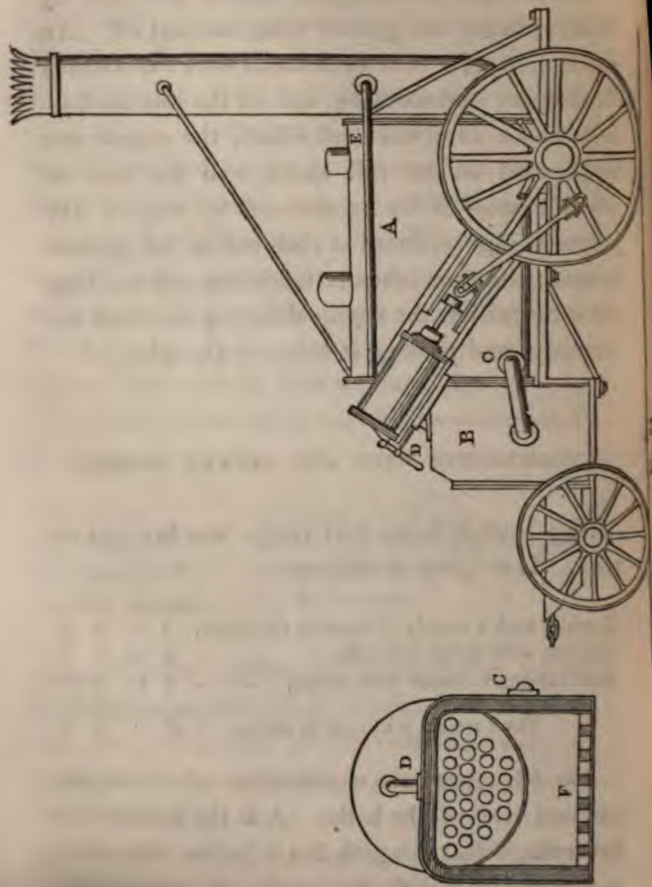


Fig. 54.

box was 3 feet long, 2 feet broad, and about 3 feet deep; at the bottom of it the fire-bars (F) were placed. It was supplied with water by the pipe (C) on the under side communicating with the boiler, and another pipe (D), at the top permitted the steam to pass into the boiler. The upper half of the boiler was used as a reservoir for steam, and the lower half filled with water. The waste steam from the two cylinders escaped into the chimney by the pipes (E), shown over the boiler in order to produce a draft.

Through the lower part of the boiler 25 copper tubes, 3 inches in diameter, extended longitudinally, opening at one end into the fire-box and at the other end into the bottom of the chimney. There were two cylinders placed diagonally on the outside of the boiler, one of which is seen in the cut. The pistons of the cylinders were 8 inches in diameter, with a stroke of 16½ inches. The cross heads of the pistons worked in guides, and by means of connecting rods transferred the motion in a very simple and effectual manner to one pair of large wheels, 4 feet 8½ inches in diameter, the pistons being so arranged in the usual manner that while one was in the middle of its stroke the other was at the end of the cylinder.

From the sketch it will be observed that the boiler, which shall afterwards be more particularly noticed, differs entirely from those of the locomotive engines previously described, as there are several tubes, instead of one large flue through the boiler, for the purpose of raising steam more rapidly by having a larger surface of heated metal in contact with the water.

From the exposed inclined position of the cylinders on the outside of the boiler, a great disadvantage arose from the loss of heat and consequent diminished power of the steam, although it had the advantage that the machinery interfered less with the play of the springs; in making their engines, however, subsequently, the cylinders were placed horizontally in a chamber under the boiler, or in the smoke-box.

The area of surface of the boiler exposed to the direct action of the fire, or the radiant heat in the fire-box or furnace, was 20 square feet; the surface exposed to the flame, or heated air from the furnace, which has been termed communicative heat, was 117·8 square feet, and the area of the grate bars was 6 square feet. The nuisance from smoke was avoided in a great degree by using coke for the fuel, but there was no plan or provision made for consuming the smoke.

The result of the experiments made on the Rocket was as follows: — The engine was taken to the extremity of the stage, the boiler being quite cold. The fire-box was then filled with coke, and the fire lighted. The time was observed which it took to raise the safety valve at a pressure of 50 lbs. on the square inch, which was 57 minutes. When the steam was at this pressure, which was at 10° 36′ 5″ o'clock, the engine started from the west extremity of the stage, and arrived at the same place, after performing ten trips, or 35 miles, including the one eighth at each end for starting and stopping, at 1° 48′ 38″ o'clock. The total time occupied was 3° 11′ 48″; and the time taken in going 30 miles at full speed was 2° 14′ 8″, being equal to $13\frac{4}{10}$ miles per hour. In the second experiment the total time occupied was 2° 57′ 9″, and the time in going 30 miles at full speed 2° 6′ 9″, being equal to $14\frac{2}{10}$ miles per hour. The maximum velocity was above 19 miles in the first journey and 20 miles in the second journey, and the minimum velocity in the first journey was $11\frac{4}{11}$ and in the second 13 miles. The greatest rate of motion attained was in the last eastward trip of $1\frac{1}{2}$ miles, which was performed in 3′ 44″, being at the rate of $29\frac{1}{9}$ miles per hour.

The eastward trip is to be taken as the per-

formance of the engine, as, in going east, the engine dragged the carriages after it, whilst, in going west, it pushed them before it; the former were invariably performed in less time. Taking the eastward trips, the average speed, conveying 17 tons, was 15 miles an hour.

The quantity of coke consumed in the two experiments was 1085 lbs., which, for 70 miles, including the engine and tender, is 0·91 lb.; exclusive of ditto, 1·63 lb. per ton per mile.

The quantity of water used was 579 gallons, or 92·6 cubic feet.

For each cubic foot evaporated, the fuel consumed was $11\frac{4}{10}$ lbs. of coke, and the evaporating power of the engine, per hour, was about 18·24 cubic feet of steam.

EXPERIMENTS WITH THE SANS PAREIL ENGINE.

The Sans Pareil of Mr. Hackworth was the next engine experimented with. This engine was not unlike Trevithick's. It had two cylinders of seven inches in diameter with eighteen inches' length of stroke. One vertical cylinder was placed on each side of the boiler, and directly under them one pair of the carriage wheels; both the

pistons of the cylinders worked the same axle. The two pairs of wheels were coupled together by connecting rods in order that the adhesion of the whole might be taken advantage of; — a plan which has since been advantageously made use of.

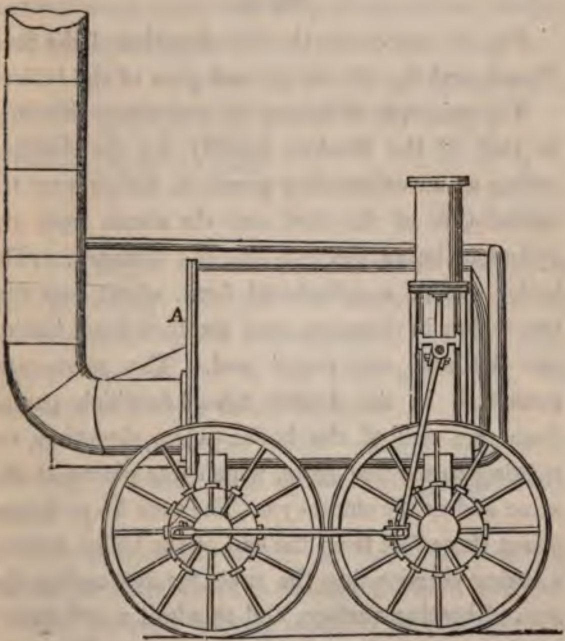


Fig. 55.

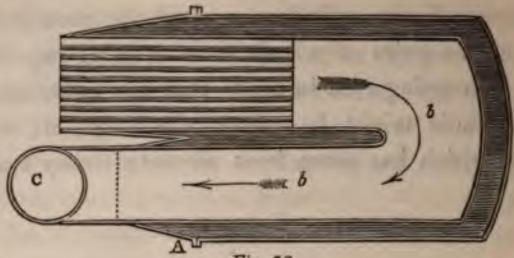


Fig. 56.

Fig. 55. represents the side elevation of the Sans Pareil, and fig. 56. the ground plan of the boiler.

The principle of raising the steam was the same as that of the Rocket, namely, by the chimney acting as an exhausting power in keeping up the combustion of the fuel, and the steam from the cylinders being ejected into the chimney. The boiler was of a cylindrical form, about four feet two inches in diameter, and six feet long, having one flat and one round end. The steam was generated in the double tube *b b*, which passed from one end of the boiler (A) to the other, returning to the fire grate, which was placed at the same end as the chimney C. The tube *b b* projected about three feet from the end of the boiler, having a casing surrounding the tube for increasing the area of heating surface, and to admit a sufficiency of air to pass through the fire-grate. The tube was two feet diameter at the fire, decreasing to

fifteen inches in diameter at the chimney. The grate-bars were five feet in length, and the area of surface radiating caloric or that surface exposed to the direct action of the fire was 15·7 square feet, and the area in contact with heated air or communicative heat was 74·6 square feet, the area of the fire-grate was 10 square feet: the two former were much less than those of the Rocket, and the last larger.

	Tons	cwt.	qrs.	lbs.
The weight of the Sans Pareil was, with water,	4	15	2	0
Tender, with water and fuel, - - -	3	6	3	0
Three carriages, with stones - - -	10	19	3	0
	19	2	0	0

This engine was tried in a similar manner to the preceding; but the last experiment was not completed from the derangement of the engine-pump: but, so far as the trial was made, the result was inferior to the Rocket.

At full speed ten miles were performed in 50′ 49″, which was equal to $12\frac{4}{10}$ miles per hour.

The maximum velocity in one trip was $16\frac{1}{2}$ miles per hour, and the minimum was $12\frac{1}{2}$ ditto.

The greatest velocity attained was in the fifth trip, when $1\frac{1}{2}$ mile was traversed in 3′ 59″, being at the rate of $22\frac{1}{2}$ miles per hour — whereas the

Rocket had traversed the same distance in 3′ 44″, or at the rate of 29$\frac{1}{9}$ miles per hour.

The consumption of coke was 692lbs. per hour, or 28·8lbs. for each cubic foot of water evaporated, being more than double that of the Rocket, and the evaporating power being equal to about 150 gallons, or 24 cubic feet of water per hour.

The coke used, including engine and tender, was 2·41lbs. per ton per mile; and exclusive of ditto, 4·2lbs. per ton per mile.

It is estimated that the performance of this engine was 19$\frac{1}{2}$ tons, or 11 tons exclusive of engine and tender, conveyed at the rate of 15 miles an hour.

EXPERIMENTS WITH THE NOVELTY ENGINE.

The Novelty of Messrs. Braithwaite and Erickson was tried on the 10th. It was a very light engine, and promised well till an accident to the boiler terminated the experiment. The principle was different from that of the other two, as the draught was produced by a blowing machine, the air being forced through the fire to produce the requisite draught.

Fig. 57. is a side elevation of this engine, show-

ing steam generator or boiler, which was its peculiar novelty.

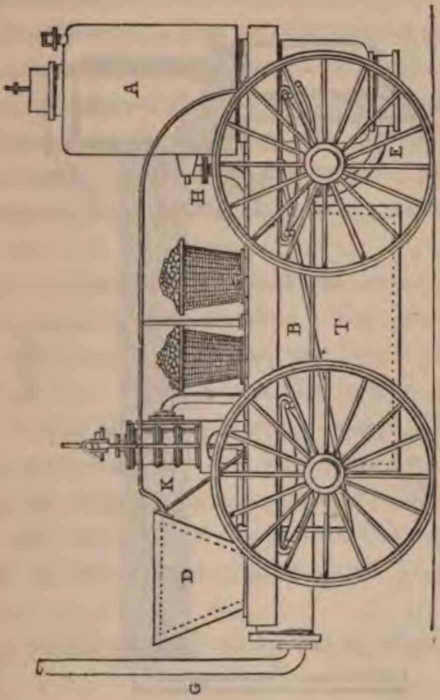


Fig 57.

And *fig.* 58. is vertical section of the same. A is the generator or boiler, arranged in the usual way, the lower part for water and the upper portion for steam; connected with this was a horizontal recipient B, which being under the level of

water in the upright generator, A, is always filled with water. The vertical tube C passes through

Fig. 58.

the generator at the bottom; it is enlarged for holding the fire-grate, F: the fuel was supplied at the top, and kept tight by sliding doors: the bottom of this tube, containing the fire-grate, was

closed, and the air was supplied through the tube E by the bellows D, which were worked by the engine, and sent the air to underneath the grate-bars for combustion. The air, after passing through the fire, was made to traverse a winding tube *e e e*, within the horizontal generator, and passed into the atmosphere through the pipe G. K is the cylinder which gave motion to one pair of wheels by means of a crank, the other being connected, when required, by a chain.

H is a pipe through which the steam passed from B into the steam chamber. The principle of operation being that the air was forced through the fire with velocity, and the heated air and flame forced along the winding tube. The area of the grate-bars was only 1·8 square feet. The surface of radiating caloric was about 9·5 square feet, and the area of communicative heat by means of the traversing tube about 33 square feet.

The weight of the Novelty was as follows: —

	Tons	cwt.	qrs.	lbs.
Engine, with water in the boiler - -	3	1	0	0
Tender, with water, and fuel - -	0	16	0	14
Two carriages, loaded with stones -	6	17	0	0
	10	14	0	14

The steam having been raised to 50lbs. pressure

on the square inch, it was tried in a similar way to the Rocket. After several attempts made to run the engine, but which were unfortunately unsuccessful, from parts of the machinery giving way, Mr. Erickson withdrew from further competition. No conclusion could be formed by the experiments of the power of this engine; or the quantity of steam which could be raised in a given time, or the fuel required for it. The whole time occupied, in the short trial made, in traversing a distance of $4\frac{1}{2}$ miles, was $22' 57''$. From a statement at the time by Mr. Vignoles, in the "Mechanics' Magazine," with a weight estimated at 10 tons $6\frac{1}{4}$ cwt., the eastward trip, $1\frac{1}{2}$ mile was traversed in four minutes and thirty-nine seconds, being at the rate of $17\frac{1}{2}$ miles per hour, and the westward trip at the rate of 15 miles per hour.

RESULT OF THE COMPETING EXPERIMENTS.

Thus terminated the interesting competition, and the prize of 500*l.* was awarded to the Rocket of Mr. Stephenson, as having performed all the conditions and stipulations required of the competitors. In reviewing the subject of this compe-

tition, it need excite no surprise that Mr. Robert Stephenson was the successful competitor, when we observe from the history of the invention of the locomotive engine, that he had long before directed his attention to it, and had thus a fair advantage over the other candidates, and from his practical knowledge in seeing the working of these machines, he knew where the defects lay; and he thus had a good chance of effecting improvements.

As the practical results of these experiments were most important to the science of locomotion, it is useful to have a clear conception of them; besides, in general this point is misunderstood.

It should be kept in recollection that till these experiments, the maximum performance of an engine, weighing with tender about ten tons, was equal to convey 40 tons at the rate of six miles an hour, the evaporating power being equal to about 15 gallons of water per hour: or to take the estimate which Messrs. Walker and Rastrick have given, after examining the different railways, that an engine weighing with its tender 10½ tons was only capable of conveying 19½ tons, or a gross weight of 30 tons, including engine and tender, on a level railway at the rate of 10 miles an hour.

When the most eminent engineers in this country were entirely at variance in opinion as to the best mode of traction, and considered it next to hopeless for locomotive engines to attain a greater velocity than 10 miles an hour, the importance of such experiments as those tried at Liverpool must be apparent. It may be proper, in explanation, to state, that amongst the erroneous opinions at this time prevalent, were, that the heavy weight of locomotive engines was an insuperable objection to their use; that they had already reached a maximum, and could not be made more powerful without injuring the rails; that as, at 15 miles an hour, the gross load carried was only $9\frac{1}{2}$ tons, no useful practical result could be obtained by such engines at a rate of speed above 10 miles an hour.

The deduction from the experiments with the Rocket proved that a reduction of three tons of the weight could be effected without a diminution of the power, and that the consumption of fuel could be diminished 50 per cent, from that of the old engines, while the steam at the same time could be generated more rapidly. This was the chief fact elicited by these experiments; for as the weight to be drawn was restricted by the stipulations, the results brought about were not the carrying a

greater load at more rapid speed, or even a greater amount of work done. The important fact was, however, developed, that the power of these engines might be extended by increasing their evaporative property, without increasing proportionally their general weight. As the power of these engines is greatly dependent on the evaporating principle, it was at once shown, that an engine of three tons less weight than another, could more easily perform the same work: if the former light engine was proportionally increased in weight it could likewise be increased in power, and the weight might be added if necessary to the steam generator, or to such parts of the machinery as might be deemed requisite to obtain the power required.

This may appear to be a very simple denouement to these experiments, which excited so much public attention; but the results were practically most important, as subsequent events soon proved. Engines were afterwards made of greater weight and greater power, for the secret had been discovered wherein lay the power; and, in place of the weight of the engine being an obstacle to its tractive agency, the arcanum of volition lay in its adaptation: this point is not generally known or understood. To the Liverpool and Manchester

experiments may be therefore attributed the discovery of the vast capabilities of locomotive engines; yet the mere contrast of these trials, with the power and rate of speed at which the same distance can now be gone over, shows how rapid has been the improvement since that time: still, in all essential principles the Rocket was so perfect, that the principles of the locomotives in use at the present day are much the same: thus at once, as it were, locomotive travelling approached to maturity.

OPENING OF THE LIVERPOOL AND MANCHESTER RAILWAY.

The Liverpool line was opened on the 15th of September 1830, and the day will be long remembered by those interested in railway affairs, associated too, as it is, with the fatal accident which deprived this country of that talented statesman Mr. Huskisson.

So great was the rapidity of transit by this railway, and the weight of goods transported, that one feeling of astonishment pervaded the kingdom. Loads from 50 to 150 tons and upwards were drawn along with ease at the rate of 20 to 30

miles an hour. All the prejudices against locomotive engines as a tractive power were at once dissipated; the eyes of the public were opened to the success, and capabilities of a mode of inland transit, which rumour, with a thousand tongues, had magnified into one fraught with danger and alarm. Friend by this rapid mode of transit has been brought nearer friend; personal intercourse has taken place instead of tardy correspondence; nations as well as districts have become amalgamated. A profitable investment of capital has been pointed out which heretofore had not been surmised; and every one may take a common interest in the road over which he travels, and participate in the profits derived from it. Such, indeed, about that time, was estimated the amount of saving to be attained by the country by the introduction of steam transit, that one locomotive engine (and that was before they had attained the perfection since done) capable of conveying 150 tons 200 miles, or 30,000 tons one mile, was considered equivalent to the daily work of 7,500 horses on a turnpike road, or 375 horses working on a railway. Notwithstanding this appreciation of the vast capabilities of this extraordinary motar for rapid motion and great power, for several years the advantages of the invention

do not appear to have been generally understood or appreciated by the country: indeed, so little must have been foreseen by many the present success of railways, that it is remarked, but a few years ago, under the head of Railway, in M'Culloch's Dictionary of Commerce, when alluding to the Liverpool and Manchester Railway, — "we doubt much whether there may be many more situations in the kingdom where it would be prudent to establish one."

From the period of the opening of the Liverpool and Manchester Railway the prodigious exertions almost exceed credibility which have been made in Britain to extend railway communication; and the commencement of so many new lines will bring the remotest districts of the country to participate in the benefits of this mode of transit. In Britain not less attention is now paid to introduce every improvement which talent can suggest, both in the construction of the locomotive engine and of the railway. In 1831 one locomotive engine drew 50 tons up the inclined plane at Rainhill, 1 foot in 96, or 55 feet per mile, at an average of 7½ miles per hour, and a steam engine was capable of drawing on a level 90 tons about the rate of 20 miles an hour. At the present

time the power of locomotive engines has been greatly increased. In 1831 the cylinders were used 10 to 12 inches in diameter. In 1832 one engine, the Sampson, had the cylinder of 14 inches; whereas engines are now provided with cylinders 14, 16, and 18 inches in diameter, and the driving wheels also have been enlarged in diameter: thus increase of power and average speed is gained. The distance from Edinburgh to Glasgow, 46 miles, which till lately took two hours fully, is now gone over by the mail trains in an hour and a quarter, and by heavy trains of waggons at 30 miles an hour; but this is *little* to some of the English railways, on which fifty miles, including stoppages, is the daily speed of swift trains, and a mile per minute, or 60 miles an hour, is frequently gone. An express train on the Great Western has gone 194 miles in 3 hours and 38 minutes, drawing 59 tons: allowing 32 minutes for stoppages, this gives a rate of 63 miles an hour; and even this hardly satisfies the impatient traveller. On the same line 194 miles is gone over in 4½ hours, which is the usual rate, including stoppages, and 40 loaded waggons are drawn with great ease. Perhaps nothing has yet been done in railways equal to America. A locomotive, constructed by Norris, Philadelphia,

is stated to have drawn on a railway near that city, a train of 158 iron coal-waggons, which weighed 1268 tons, turning curves of 700 feet in radius with facility, and going over a distance of 84 miles in 8 hours and 3 minutes.

By successive improvements made in locomotive engines, such as inclosing the cylinder, already noticed, and which was exposed in the Rocket, and by casing with timber the boiler, the fuel, 2·41 lbs. of coke, required to transport a ton per mile by the Rocket at the opening of the Liverpool line, has been reduced to a quarter of a lb., or even less, consuming a $\frac{1}{4}$ gallon of water. The inclosing of the cylinder in the smoke-box at the front of the engine has been a great improvement, as a great waste of heat arose from the rapid motion through the air. The chamber where the cylinder is placed receives heat from the end of the boiler-tubes, while a direct action is attained between the piston rod and the connecting rod to the crank axle and eccentric fixed on it, which works the slide valve. Another great improvement in the construction of the locomotive engine is considered to be the blast pipe. Before the blast pipe was introduced the locomotive engine is stated to have made comparatively little noise, for the steam escaped

directly into the atmosphere. The blast pipe receives the steam after its exit from the cylinders at each stroke of the engine, and conducts it to the bottom of the chimney, where it is blown up with the flame and hot air rushing through the tubes in the boiler towards the chimney, the blast pipe being proportionate in diameter to the chimney.

DESCRIPTION OF THE MODERN LOCOMOTIVE ENGINE.

The improvements in locomotive engines have of late years followed each other so rapidly that it is barely possible to detail them. The main and distinguishing features, however, remain the same.

Having given a sketch of the history of the locomotive engine from the invention of Trevithick till the improvements effected on it by the contest on the Liverpool and Manchester railway, I shall now give a brief description of the engine as at present used in this country, on the continent, and in America. Although it is necessary to observe that, from the frequent alterations making in the details, or different parts of it, any description but of a general kind must be

imperfect; it is impossible to explain the various parts without full drawings. The cuts annexed

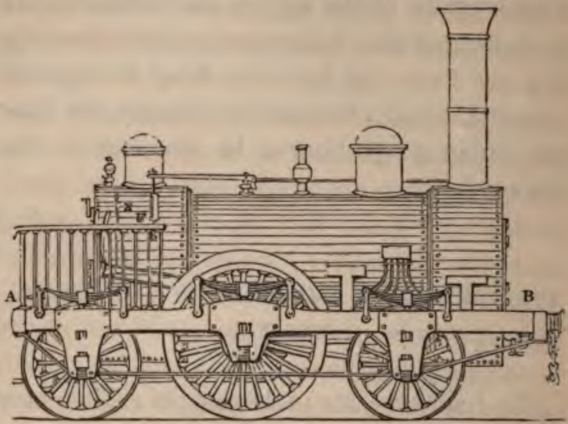


Fig. 59.

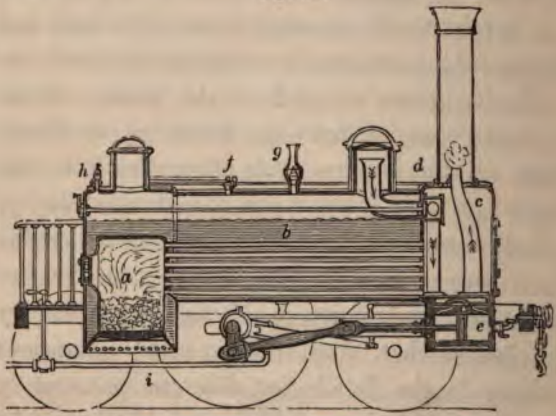


Fig. 60.

will serve, therefore, merely to give a general idea of the formation.

Fig. 59. is a side elevation of a locomotive engine, and *fig.* 60. is a longitudinal section of the same.

The boiler is represented (*fig.* 59.) cased with wood in order to economise the heat and prevent radiation, and sometimes flannel is placed between the iron and wood; the steam dome (usually of polished brass) and other parts, are made double.

By referring to the cut of the Rocket engine (*fig.* 54.), it will be observed that the cylinders are exposed at the sides of the boiler, whereas in the modern engines, for the reasons assigned, the cylinders fixed to the frame-work of the boiler are placed horizontally, concealed, and kept at a high temperature under the boiler, in the chamber into which the heated air passes from the tubes in its passage to the chimney; but when very powerful engines are required in working up steep inclines for short distances, it has been the practice, in order to obtain more room for the machinery, to place the cylinders diagonally outside the boiler, as shown in *fig.* 54. The powerful engines at the tunnel near Glasgow, on the Edinburgh and Glasgow Railway, and elsewhere, are made in this manner.

The engine (*figs.* 59. and 60.) is represented

mounted on six wheels, which is the plan now generally adopted, although for a long time, notwithstanding the stipulations of the Liverpool and Manchester contest, engines on four wheels, as in the oldest plan, were used. The large central wheels are called the driving ones, and some engineers have removed the flanches from them to get rid of the lateral strain, having considered the flanches on the two pair of small wheels were sufficient for guiding, and use the large ones more for propelling or rolling the engine. Other engineers retain the flanches as an additional security, to prevent the carriage running off the rails. The size of the driving wheels are adapted to the views of the engineer in respect to the power of the engine and gauge of the railway; they are commonly from 5 to 7 feet in diameter, and the small wheels from 3 to 4 feet, and $4\frac{1}{2}$ inches broad.

Coupled driving wheels are now common both in this country and in Belgium, for obtaining greater adhesion in ascending inclined planes. It has been estimated that a locomotive, with coupled driving wheels of $4\frac{1}{2}$ feet diameter, and 14-inch cylinders, could ascend an incline with one-third more weight than a locomotive with 5 feet wheels and 12-inch cylinders, if uncoupled.

The diameter of the cylinders of locomotives must vary according to the power that is required. The piston rods of the two cylinders are kept in their parallelism by means of slide bars, and move horizontally under the boiler, and work, by means of two connecting rods, two cranks which are forged on the axle of the driving wheels. The cranks are so made that when one crank, in working, is horizontal, the other stands vertical. The object of this is, that there may be a uniform and certain rotatory motion of the wheels, which could not be if both cranks were in the same position at one time. Thus while one end of the connecting rod from the piston keeps up an alternating rectilinear motion, the other, by means of the crank, preserves a continuous rotatory motion.

The slide valves, or parts of the engines which admit the steam to the cylinders, are placed on the upper side of them, and are worked or moved backwards and forwards by means of eccentrics, in a similar manner to all reciprocating engines. These eccentrics are sheaves or rings fixed on the axles of the driving wheels on false centres. In one revolution of the axle the extent of the rectilinear motion produced by each eccentric is equal to the distance that the slide moves on the

face of the cylinder, so that by every revolution of the axle and crank the slide is moved so far in each way, as to allow the steam, from its pressure, to rush into the cylinder alternately above and below the piston, and give it a reciprocating motion. This is the first action of the steam power, the *primum mobile* which gives motion to the whole machine, or the vivifying principle. From the construction of the eccentric, when the engine is going the slide valve is constantly in motion; for whenever the apertures, or ports, are open, the reverse movement of it shuts them again. Two eccentric wheels for working each cylinder are now generally made use of, in locomotive engines, each of which is placed in a proper manner to admit of the engine moving either forward or backward. This plan is necessary for all engines adapted for rapid speed.

It has been found that when engines travel at great velocity, the expansive system, found so beneficial in high pressure engines, can be carried still farther with advantage in locomotive engines. The object of the expansive system is, that the expansion of the steam within the cylinder, when the engine is set in motion, combined with the impetus acquired by the piston, will communicate additional motion to it and accelerate the velocity

of the stroke; hence, that the steam may be effectively and economically stopped from entering the cylinder before the piston has reached the end of the stroke (at a quarter or one eighth), and it should not only be shut off from the piston before it reaches the end of the stroke, but should be applied to the opposite side of the piston before it reaches the end of the cylinder, or the slide should at the extremity of the stroke be opened to a certain extent.

It has been considered by some engineers that one eighth of an inch produced the best effect for cutting off the steam from the bottom of the stroke, or in other terms, that the slide valve should be open to this extent at the return of the stroke. The exact extent, however, is regulated by the velocity of the piston. The advantage gained in saving or economising steam by this method will increase in proportion as the steam is sooner cut off, at the same time not diminishing the efficient power.

A is the platform, at the end of the fire-box (*fig.* 59.), for the use of the engine driver, and from which the fire can be fed and the engine managed. At the other end, B is the smoke-box, from which the chimney proceeds. The boiler or steam generator occupies the space between

the two; the brass tubes for the passage of the smoke and flame opening into the fire-box at the one end and the smoke-box at the other. The fire-box is usually now made of strong plates of copper with the outer casing of iron, the intermediate space of three or four inches being filled with water, and forming a part of the boiler. It is commonly open below for the access of the air, from which place the cinders falling through the furnace-bars, which are usually made of malleable iron, has been productive of accident. There are several inches of water always over the flat top of the fire-box, the water being carefully kept to this level: when the water in the boiler is too high the engine begins to prime; when too little, the top would be instantly burnt through. A fusible plug is inserted, to serve as a safety valve, should the water, by accident, get too low and leave it dry. From the small quantity of water in locomotive boilers, the boiler is apt to prime or the steam to be condensed in the steam passages, and the steam in the upper portion becomes mixed with the spray in ebullition. Hence a steam chamber is provided on a higher level. This dome is seen in polished brass on locomotive engines; it is made with a double case, to prevent loss of heat from radiation. The steam from the

chamber is conveyed in the usual manner to the cylinder (*e*) of the engine, the steam pipe passing through the smoke-box. The blast-pipe, which conveys the waste steam from the cylinder to the chimney, may be observed passing up the middle of the smoke-box, the upper end of which is tapered, that the jet of steam may have more effect when escaping in increasing the current, as the extracting power or vacuum movement of the air in the chimney and draught of the fire is increased by it. It is the passage of the steam from the cylinder escaping through the blast-pipe into the atmosphere that produces the snorting or puffing noise heard. The strength of the draught through the chimney carries up the cinders from the fire and scatters them, producing accidents; to guard against which a gauze cap is frequently placed at the top of the chimney or a grating at the bottom of it, as shown in cut, before the cinders are under the influence of the jet of steam: *f* is the safety valve, which is under the control of the engine driver: *g* is another valve. These valves are held down by springs. *h* is the steam-whistle, which is a modern contrivance for creating an alarm, serving as a signal from the noise the steam creates when rushing out at a narrow circular slit in the lower half of a brass ball and

striking on the edge of a hollow inverted cup. The steam is led to the whistle by a tube from the boiler, and is regulated by means of a stop-cock. *i* shows one of two feed-pipes, which conduct the water from the tank in the tender to the boiler, the water being pumped into the latter by small forcing pumps placed under it. These pumps are worked by the engine, and their derangement has often been productive of serious accidents. There are valves for regulating an equable supply of water to the boiler, and the waste steam may be turned into the tender-cistern to heat the water. There are discharge cocks for removing condensed water, steam and water gauges, and other conveniences placed under the observation of the engine driver, handles for stopping and reversing the motion of the engine, and regulators for the draught of the fire.

The regulator for increasing or diminishing the supply of steam to the boiler is a disc or throttle valve placed in each of the pipes which supply steam to the cylinders. These discs are fixed on the end of a horizontal rod, passing the whole length of the boiler, and turned by a handle at the platform, so as to open or shut the passages. At this handle is a graduated scale for indicating the degree the throttle valves are open, so that by

the turning of the handle the supply of steam is instantaneously increased or cut off from the cylinder.

Every locomotive engine has a carriage connected with it called the tender, which is used for carrying a supply of water and coke. The tender is made with a frame-work like other carriages, and on most railways has usually four wheels. The water is contained in an iron tank surrounding the sides of the carriage, excepting the end next the engine, which is left open for the convenience of getting access to the coke. The boiler is, of course, connected with the tank by means of the supply pipes already noticed, and the tank is supplied with water at various stations on the line of railway by water-cranes and cisterns, according as the engine requires water. The tender is just so much additional necessary load that every travelling engine must carry along with it.

LOCOMOTIVE ENGINE BOILERS.

It must appear obvious that in the construction of the boiler of the locomotive engine a great object was to combine with sufficient lightness,

compactness, and safety, the greatest possible heating power; for as the power obtained will be in proportion to the heat transmitted from the fire to the water, and then available as steam, the amount of fire in the boiler will be the measure of the heat, and the smaller the quantity of fuel in an active state of combustion which can be brought to bear to keep a small quantity of water at a high degree of temperature, the more efficient the boiler will be: hence the rapid formation or evolution of heat depends on its abduction from the fuel in such a manner that no loss is sustained in its extrication. In locomotive engines, therefore, for generating steam quickly, while a powerful draught is indispensable, it is a great object to expose the smallest quantity of water to the largest heating surface which the heat radiating from the furnace can act upon, and that every means be adopted by non-conducting substances, as jackets or linings of flannel and wood on the boiler, to retain the caloric which has been evolved. The various contrivances to attain these objects would fill volumes.

When Mr. Stephenson's engine, the Rocket, was first tried, as has been stated, 25 tubes of 3 inches diameter were made use of in the boiler, containing 117·8 square feet of heating surface.

The idea of using many small tubes to conduct the heated air through the water to the chimney in their present form is allowed to have emanated from Mr. Henry Booth, of the Liverpool and Manchester Railway Company. It is unquestionable that the success of the locomotive engine made by Mr. Stephenson was in a great degree due to this adaptation. There can be, however, little doubt that the idea of using tubular boilers in different arrangements for the more rapid generation of steam is of old standing. It forms a principle of Woolf's boiler, of Mr. Julius Griffith's, as also of Mr. D. Gordon's patent boiler in 1825, and of others. The very decided superiority of the plan of Mr. Booth's and Mr. G. Stephenson's boiler for increasing the surface of water in contact with the heated air passing through it not being patented, led at once to its being generally adopted for locomotive boilers; and since that time the principle has been applied to marine boilers; and several engineers are now constructing many of their marine boilers on the tubular principle; the tubes are made of malleable iron from 3 to 5 inches diameter. It is still, however, doubtful how far this principle is suitable for the marine boiler; for the locomotive boiler there can be no doubt of its eligibility.

Mr. G. Stephenson had soon discovered the advantage to be derived from enlarging the heating surface of the cylindrical boiler, by increasing the number of the tubes, to abstract or absorb the caloric from the heated air. The diameter of the tubes was reduced from 3 to $1\frac{5}{8}$, or two inches, and the number increased, varying from 90 to 150, with a surface of from 200 to 300 square feet exposed to the contact of heated air. The heating surface, of late, has been greatly augmented, both in tube surface and fire-box: but the opinion is not in favour of having the tubes very small; they are usually made about two inches diameter inside, and from 73 to 120 tubes in each engine, — the number of tubes being dependent on the diameter of the boiler. With improved engines the tube surface has been increased from 400 or 500 square feet of heated metal, exposed to communicative heat, to the enormous extent of from 600 to 800 feet and upwards, with a fire-box surface or area exposed to the radiant caloric increased from 20 square feet, as in the Rocket, to from 50 to 60 feet; and with the broad gauge engines on the Great Western, the tube surface has been increased from 600 to about 1000 feet, and fire-box surface from 70 to 108 feet.

As the upper side of the fire-box is flat, and

not adapted to bear a great pressure of steam, bolts are placed betwen the chamber and the fire-box to resist the pressure. In the lower part of the boiler the tubes are placed, running through its whole length.

Copper was first used in the construction of the tubes; but they are now always made of brass, and have been found much more durable. The opinion seems to prevail that making the tubes of mixed metal, or the best rolled brass of No. 14. wire-gauge is the preferable method, the tubes being secured at the ends with steel and iron hoops. Some have thought that as malleable iron of good quality is less expensive, it would answer the purpose, as it does for the tubes of marine boilers; but copper or brass would be generally used for all boilers, from its durability, were it not for its great expense. The tubes must always bear a constant working pressure of about 60lbs. on the square inch, while the form of the tube gives an advantage in their strength, as the pressure on the tube must be inward, from being surrounded with water. The tubes, however, are necessarily subject to great waste, from the constant action of the cinders and ashes upon the interior surface: another thing which operates against their durability is the want of an equal

expansion between the case of the boiler and the tubes. This may lead ultimately to almost an entire reconstruction of the engine and boiler; although, therefore, the tubes must be frequently replaced, for they usually last for about two years, and so are not of the permanent nature of such parts of the boiler as are not exposed to the action of the flame, and while tubes will burn out, and may frequently burst, still these boilers have been constructed capable of running a distance of 30,000 miles before requiring to be renewed; and the broad gauge engine boilers have been stated to run 70 to 80,000 miles. A very erroneous idea seems to be entertained that no danger can arise from the bursting of a tube in locomotive boilers: indeed the bursting of tubes is so common, that the engine drivers become accustomed to it: but it is always attended with the next to certain danger of scalding, perhaps to death, the fireman or engine driver, from the steam rushing out at the fire-door, and cinders being blown about, while alarm is created, and danger arises to the passengers from the delay and stoppage. When a tube does burst, it is customary for the engine driver to be prepared with a plug ready to drive into the aperture till the boiler can be repaired.

From the perishable nature of the tubes and end of the boiler exposed to the direct action of the fire, various expedients have been proposed, and some engineers have thought that a boiler constructed on the principle of placing the water in the tubes to be heated, instead of the fire in the tubes, would be more durable and as efficient. The Earl of Dundonald and others, years ago, proposed boilers on this principle. Mr. A. M. Perkins, of London, has a patent for a boiler, which would be exceedingly durable if found to answer the purpose of locomotive engines. The steam is generated with great rapidity in a recipient, or strong iron vessel, by the water therein coming in contact with a considerable extent of surface of small tubes within which water is heated, under high pressure, to above the boiling-point. The water in the tubes is heated by means of a portion of the same tube, which heats the water in the steam generator, being exposed in a furnace to the direct action of the fire. The report which has been published of Mr. J. Parkes, C. E., was highly in favour of the evaporative properties of this very beautiful and ingenious contrivance, as also its safety and durability, and economy of fuel, and the strongest and most satisfactory evidence has been adduced as to its advantages and utility.

EXPLOSIONS OF STEAM BOILERS.

The dangers arising from steam-engine boiler explosions are so great, that any plan of construction which could completely obviate this, is deserving of consideration; and the idea of a boiler, such as that last described, where the steam is generated in a vessel not exposed at all to the action of fire, is a novelty, as well as a complete security against the risk of its getting red hot from a deficiency of supply of water. In the present construction of the locomotive engine boiler, the only security, as to its safety in this respect, depends on the regular maintenance of the level of the water in the boiler; for as the tubes are exposed to the direct action of flame, they would be instantly destroyed by any diminution of the supply of water, which might happen by the least derangement of the feed pumps.

From the high pressure the steam is always worked at, in locomotive engines, generally above 50lbs. on the square inch, two safety valves are always used; one is under the charge of the engineer, commonly called Salter's flat-sided, spring-balance: it has a lever between the valve and

spring. The other is now generally locked up, and has a series of bent springs, without a lever, compressing it.

Every engine boiler, besides the three common gauge cocks, should have indices of pressure, as the simple glass water gauge, to show in a glass tube the height of the water in the boiler. This tube, part of which is of brass, communicates by a cock at the top with the steam, and at the bottom with the water in the boiler, and there is another cock, at the lower end of the tube, to let off the water. The dynamometer, or bent tube with mercury and a float, and the piston gauges are also good indices of pressure. All these precautions, however, do not appear sufficient to prevent accidents. It has already been stated that the practice in some locomotive boilers is to place a fusible plate on the top of the fire-box; but this principle might be extended still further, to guard against explosions. It was several years ago made an imperative rule, by the law of France, that a plate of fusible metal, half an inch thick, made of lead, tin, and bismuth, should be placed on the top of the boiler, close to the safety valve, and held in its position by an iron grating above it: should the valve not rise, the heat, before the pressure of the steam could have increased to

a dangerous extent, will melt the safety plate and allow the steam to blow off. It would be a proper thing if such a rule was made imperative in this country, where steam power is so generally made use of. Every locomotive engine boiler should have, therefore, a fusible plug over the fire-box, composed of four parts of lead and one part of tin, which would melt before danger would arise, and blow into the furnace. Objections, founded on experiment, have been started, that the fusion of an alloy of metals, as proposed by the Ordonance of France, can only be depended on when the metal is not exposed to the action of the steam, that is, to its pressure, but merely to its temperature: the remedy is, enclosing the fusible metal in a case not exposed to the pressure of the steam. This subject of fusible plugs has been thoroughly investigated in America by the Franklin Institute.

These precautions are the more necessary from the ignorance which, it has been observed, still exists, "not only of the power, but even of the nature of steam." While all admit the danger of steam explosion, few of the causes of these explosions are satisfactorily explained; and no perfect or even certain method has yet been devised to guard against them. A railway accident, such as

the engine running off the rails, may be greatly aggravated by the explosion of the boiler.

It is worse than folly to intrust an agent as potent as gunpowder to the hands of the ignorant and unskilful; and yet we often see men in the charge of steam boilers without skill or experience, and who may, in one moment, involve themselves and all around them in common destruction. It is the more to be regretted that when science has made the agency of steam so tractable, there should yet exist the least danger in its use. For how dreadful must be the power of steam explosion, when tons of metal are blown into the air like a rocket, and sent to a vast distance! Only a short time since, a boiler weighing $3\frac{1}{2}$ tons, exploding at a work on the Surrey canal, was blown 200 feet high, and fell about 300 feet from its site. At another recent case near Manchester, a portion of the boiler, 26 feet, weighing 2 tons, was shot like a cannon ball, a distance of 40 yards. At Barnsley, recently, by the explosion of the steam engine boiler, a cotton mill was destroyed, and not a vestige of the building was left standing. At another recent frightful accident in Bolton, several lives were lost by the explosion of a boiler, and one end of a cotton-mill was blown up with a tremendous crash.

That too much precaution cannot be taken to guard against explosions with locomotive boilers, has been proved by the accident on the Dover Railway, and by the explosion of the Irk locomotive on the Manchester and Leeds Railway, where several persons lost their lives. Various other casualties have occurred of a similar kind. A few years ago an explosion took place on the Liverpool and Manchester Railway, supposed to have arisen from the case or shell of the boiler being weaker than the tubes. That doubt should for one moment exist as to the real cause of such fearful explosions, as that in the case of the Irk, when the engine carriage was blown to a considerable distance, and the unfortunate engineer and fireman to the distance of 20 yards from the site of the explosion, and 21 yards of the roof of a shed blown away, are things which show how very imperfect engineering knowledge is, still, on this point.

This accident has been attributed not to any derangement of the valves, but to a rent made in the fire-box, by which means a body of water thrown upon the fire was instantly converted into steam of high density, bursting as a shell from a mortar, and producing the somersault described. This rent was attributed to the excessive

heat from the quantity of fuel in the fire-box, "about 2 feet thick, which, when the engine was at work, by means of the draught of the blast pipe, is kept at a white heat." But this rent is the effect, not the cause of the explosion: no action of the fire on the fire-box could produce the rent stated, unless either the valve was overloaded, or there had been a deficiency of water in the boiler. The cause of the accident must, therefore, either have arisen from an excess of pressure or a deficiency of water. Supposing the boiler had a flaw or crack in the metal plate over the fire, as stated in evidence at the coroner's inquest, as the boiler had long stood the general pressure, the probability is, this flaw was expanded by neglect of water in the boiler, when the excess of pressure would act on the weakest point.

The evidence on this occasion sufficiently proves the necessity of a proper system of neutral inspection and surveillance of railways for the public security; for it is just as reasonable to apply a system of inspection for conveyances for inland transport as in maritime matters to adopt Lloyd's survey and classification. The accident alluded to could not have happened without inattention, or perhaps great negligence. We are

informed that the safety valves of the boiler were of the usual kind, $3\frac{1}{2}$ inches diameter, and the engine was generally worked at about 60 pounds of pressure on the square inch; but we also have it in evidence that the men worked by *contract;* that their interest was to save coke, which was weighed out to them; that the engineers were paid a certain sum per mile, out of which they had to pay their own oil and tallow, and had also to pay their own fireman. One of the witnesses stated "that he seldom saw steam blown off from the contract engines, and in starting with heavy loads, the engineer put his hand upon the spring-balance of the valve, one of Salter's flat-sided ones; this enabled them to start better."

It thus appears, that in order to save coke, steam was allowed to accumulate at the most dangerous time, before the engine was set in motion, and the engineer, in a fool-hardy manner, runs the risk of blowing up himself and all around him, merely to save the value of a few pounds weight of fuel. One can hardly conceive a more dangerous arrangement in respect to security to the public than contracting to work engines in this manner.

PRINCIPLES OF ATMOSPHERIC PROPULSION.

The rise, progress, and construction of the railway system has now been described, and a short account has been given of the motive power which has conferred on it nearly all its importance as a medium of transit, and of which power it may in truth be asserted, that a more ingenious and beautiful application of the force of steam never was devised. It is, however, impossible to overlook that an antagonist power has, of late, sprung into existence, which seems likely to prove to it a formidable rival, namely, the atmospheric system.

One strong argument in favour of the mode of propulsion by atmospheric pressure is based upon its less liability to accidents. Much of this opinion is merely conjectural — as around the whole system considerable uncertainty still hangs: one thing, however, has resulted from the numerous and fatal accidents which have occurred under the locomotive system, that it has induced the attention of scientific men to be turned to the discovery and arranging of new modes of railway construction, such as the atmospheric, hydraulic, and other principles, and to do away

with locomotive engines entirely. With respect to new plans, they display exercise of the inventive faculty, and some good may spring from them; but it has been seen that from the rapidity with which railways have sprung into existence since 1830, that there has not been sufficient time for matured experience to perfect details: and locomotive transit is still attended with all the imperfections attaching to the infancy of a system. It is probable, however, that more good will arise by attempting a judicious remedy for evils appertaining to a system than by overthrowing it. Experience teaches, and still more the history of human invention points out, that perfection is gained by slow degrees. Whatever may come of the atmospheric principle, with which so much has already been accomplished, and upon which so much ingenuity has been displayed — nevertheless, until experience has fully proved its advantages, it would be mere folly to reject all the experience already so laboriously acquired in locomotive transport, at least, on the ground of liability to accidents, which, undoubtedly, prudence and caution may, in a great measure, avert.

The atmospheric principle in its application on an extended scale in these times has been ascribed to various individuals. The knowledge of the

elasticity and compressibility of the air is of old standing. The ancients, however, had very erroneous ideas on these points. The belief of Aristotle, that "Nature abhorred a vacuum," extended its fallacy over many of the doctrines propounded by the philosophers in Europe until the period of Galileo, who discovered that the weight of the air was the true cause for many of those simple phenomena which had puzzled preceding ages,—such as the rise of water in pumps and syphons. The atmospheric principle of propulsion is intimately associated with the interesting science of dynamics. The pressure of the atmosphere is estimated at from 14 to 15 pounds on the square inch at the level of the sea, subject to certain variations.

The physical law being clearly established, that the globe is pressed on all sides by a weight of air equivalent to that indicated by the barometer, and as this pressure must always be in operation, it follows that every object on the surface of the earth must sustain a superincumbent pressure equivalent to the square inches of surface it presents. Supposing, for example, that the surface of the human body measured 2000 square inches: this multiplied by 15 lbs., the atmospheric pressure at the level of the sea, would give a pressure

equal to 30,000 lbs. The reason why this enormous force is not felt, or that one is unconscious of the weight, is, that the pressure acts uniformly in every direction, and that air fills all space; but should the equilibrium be destroyed, then the effect is at once made palpable. The simplest experiment for ascertaining this fact is to place the palm of the hand over a cylinder from which the air has been exhausted; the pressure on two square inches would be equal to 30 lbs. of ponderable matter upon it. One may easily, therefore, conceive how so powerful, and wonderful, and ever-present an element as the pressure of the air should have been thought of as a moving power to set machinery in motion; for a moveable piston travelling or working in a cylinder or tube from which the air has been exhausted will be pressed equal to the number of square inches of surface: thus a surface of 12 inches square, or 144 square inches, would be pressed by a weight equal to 2160 lbs., if the mercury was exhausted to 30 inches; or in a pipe of 15 inches diameter, the surface area of which would be equal to above 176 inches, making the force of the external atmosphere impelling forward a piston within it equal to 2640 lbs. weight; but as a complete vacuum cannot be attained, the pressure will be regulated

in a greater or less degree according to the completeness of exhaustion of the air in the tube. Supposing, however, that the vacuum obtained was only 10 lbs. per inch, the atmospheric pressure on the piston would be equal to 1760 lbs. weight. It is necessary to keep in view that the pressure of the air is not merely variable within a very limited range from physical causes, but its rarefaction increases according to a uniform law in proportion to its elevation above the level of the sea. In ascending a height the mercury falls, being progressively relieved of the superincumbent pressure; while, on the contrary, in the lower levels, as in the depths of mines, it rises, from the density of the column being increased. This discovery was first made by Descartes in Sweden, and about the same period, 1648, by the French philosopher Pascal. It has been ascertained that a fall of $\frac{1}{10}$ of an inch of mercury is nearly equal to 90 feet of altitude, and so on, according to the elevation: thus a simple and useful method is obtained for readily ascertaining the levels of a country, making allowance for the alternations of temperature and variations of the atmospheric pressure.

One of the most useful inventions connected with aërology is the air-pump, which was in-

vented by Otho Guericke, of Magdeburg, in Germany, about the year 1664. An air-pump was, contemporaneous with that of Guericke, invented in this country by the eminent philosopher, the Honourable Robert Boyle, F.R.S. As it was considered of great importance in philosophical investigations, much ingenuity was displayed in perfecting it. The chief use, however, of the air-pump, till within recent years, was confined to experimental or philosophic purposes. The present age, however, being one of practical application, the knowledge which philosophers confined to theoretical illustrations has been made subservient to purposes of utility, and the air-pump has been applied of late years on a most gigantic scale, both to atmospheric propulsion and other uses.

When the pressure of the atmosphere became known to be regulated by immutable laws, the advantages to be derived from using it as an impelling force soon became appreciated. When steam engines were first invented they were termed *atmospheric* engines, because they were made to act through the pressure of the air by the combined effect of its weight and elasticity. The idea, however, of producing motion by atmospheric pressure, or what is now termed the

atmospheric system, has been generally ascribed to Denys Papin, an ingenious French engineer. Papin constructed, about the year 1695, a machine in which the pressure of the air should be used as a mechanical agent for effecting a partial vacuum in a cylinder. To attain this, he made a water-wheel work an air-pump to produce the rarefaction. He tried in this country a method of transferring the action of the moving power to a great distance. The ingenious idea occurred to him, that he could make a fall of water at some distance from a mine or coal-pit work a piston to compress the air in a cylinder communicating, by means of a pipe, with another cylinder at the mouth of the mine, and that the piston of the latter should, from a connecting-rod, give motion to pumps at the bottom of the mine. He calculated that the pressure of the air in the one cylinder would force up the piston of the other, and give a reciprocating motion to the pumps. This plan was not successful; but much of the want of success has been attributed to the not knowing the retardation in its motion which air suffers in its passage through pipes. Papin afterwards tried this plan on a large scale in Germany, but with little better success. He likewise at-

tempted to produce a vacuum by the use of gunpowder, but his plan did not succeed.

These facts — and numerous others might be given, even of a later period — show the disappointments which have been experienced and the difficulties met with in bringing inventions to the test of practical usefulness. They may afford a useful lesson, to prove how much needless expense may be incurred in trying complicated and roundabout processes to attain an object, when, perhaps, the principle on which the invention was founded was not merely defective in itself, but were the plan even successful, its complication would overbalance all its advantages. How often is admiration elicited by expensive and childish models, the only tendency of which is to mislead, and which, if stripped of their tinselry, and reduced to the real object they seek to attain, would be found in practice useless and absurd. Wherever simplicity is overlooked, and the working of the machine is a labour in itself, it may be well doubted if it will be of real use.

ATMOSPHERIC RAILWAY SYSTEM INVENTED.

The invention of the atmospheric mode of propulsion has by some writers been ascribed to

Papin; but it has been shown that his ingenious contrivances for exhausting and compressing the air led to little practical result. From the time of Papin the subject of working machinery by atmospheric pressure slept for a century, when it was revived both in this country and in others. The subject was taken up successively by different persons, and among others by Mr. Pinkus and Mr. Clegg, by the latter of whom, in conjunction with the late Jacob Samuda *, the atmospheric railway system, under their patent, was practically demonstrated.

The first experiments on the atmospheric principle were not very successful or encouraging, and created much doubt as to its advantages or practicability. In 1840, however, Messrs. Clegg and Samuda had an opportunity of trying their plan on a small portion of the Thames Junction, or West London Railway, near Wormwood Scrubbs: on this line a temporary experimental way, about one mile and a half in length, was laid on an incline, rising about one foot in 115 or 120. The result of the trials, even on an imperfectly level track, was, that a speed of thirty miles an hour

* The invention of Mr. Samuda was claimed by Mr. Griffiths before the Court of Chancery, but the decision was against the latter.

was obtained with a load of about six tons, and twenty-two miles with a load of eleven tons. The atmospheric tube was only nine inches internal diameter, and a vacuum equal to a column of mercury of $23\frac{1}{2}$ inches was obtained. As the engine and mode of propulsion were publicly exhibited for some time, and were seen by many persons interested in the railway system, a good opportunity was afforded for the development of the utility of the system. Amongst others, the directors of the Dublin and Kingstown Railway were so satisfied with the success of the experiment, that they resolved to adopt this method of traction upon a short extension of the line, $1\frac{3}{4}$ mile from Kingston, near Dublin, to Dalkey, where the gradients and curves of the line were considered by their engineer as unsuitable for the working of locomotive engines. This railway was accordingly prepared for the atmospheric principle. It was opened in August, 1843, and it is still worked in this manner. From the period of the commencement of the Dalkey branch till its completion no farther movement was made by railway companies towards adopting the atmospheric principle, and public curiosity was excited to ascertain the result of the experiment. At length, the London and Croydon Railway Company resolved, from

an extension of traffic, to lay down a third line of rails, and were so satisfied as to the success of the atmospheric plan, that they obtained an act of Parliament, in 1843, to construct a single line of atmospheric railway from London to Croydon, and to make an extension of the same from Croydon to Epsom. As the part of it now formed runs close to, and parallel with, the locomotive line, a fair comparison can be made of the relative merits of the rival modes of traction, and data will be afforded for the guidance of other companies who may wish to adopt the atmospheric system. It is proposed that the line shall be extended, should the plan succeed, from Epsom to Portsmouth, the part now forming being a portion of what is termed the "Direct London and Portsmouth Railway," for which a bill was obtained in the last session of Parliament. The South Devon, and Paris and St. Germains companies are said to have also adopted this system, and various lines are now projected, and companies formed to apply for acts. One of the most extensive of these schemes yet projected is a direct atmospheric railway from London to Northampton. But the prospect of obtaining an act for an extensive railway of this kind, as yet, must be doubtful, seeing that Parliament in the session 1845, after

a protracted contest, threw out the bill for constructing an atmospheric railway from Newcastle to Berwick. The following is an extract from the Committee's Report, July, 1845:—

"But your Committee do not feel called upon to express an opinion on the relative merits of the atmospheric and locomotive systems, or on their comparative applicability to railways in general. For, even assuming the efficiency of the tractive power under the atmospheric system, and admitting the proposed Northumberland line to be unobjectionable in an engineering point of view if worked on that system, still the evidence taken before your Committee does not justify them in coming to the conclusion that a single atmospheric line, with the arrangements at present in contemplation, can carry the estimated traffic between Newcastle and Berwick with the same convenience and punctuality which are already attained by the locomotive lines of which it would be a continuation."

KINGSTOWN AND DALKEY ATMOSPHERIC RAILWAY.

On the Dalkey branch, where this mode of propulsion was first adopted on a public railway, upon an incline rising one foot in a hundred, a continuous cast-iron pipe, of about fifteen inches in diameter, and a mile and a quarter in length, is laid horizontally between the rails on which the carriages run. A stationary engine is placed at

one end of the pipe to work an air-pump, which exhausts the air from the main pipe. The exhaustion extends to a column of mercury of twenty-two and a half inches, indicating the degree of vacuum produced throughout the pipe. The motion of the carriages is effected by means of a travelling piston within the tube, which is forced along by the pressure of the atmosphere, dragging the carriages with it, the piston and the carriages being connected together by a strong iron plate; the latter sliding along in a continuous slit or groove on the top of the pipe, having a valve which opens as the connecting arm passes, and closes after it to preserve the vacuum. The pressure is of course regulated by the extent of the exhaustion of the pipe and the extent of surface of the piston. On this railway three loaded carriages have been propelled up an incline, rising one in a hundred, at a speed exceeding forty miles an hour.

The chief difficulty in this system of traction obviously arises from the rupture of the pipe by the progress of the carriages: the vacuum is thus disturbed by leakage of air into the pipe. To overcome this, much ingenuity has been displayed in the construction of the valve, the mode of raising it, and of restoring it to its original

position; so as the pipe may continue air-tight and the vacuum be again prepared ready for the propulsion of another train. For it will at once be seen that leakage of the pipe must be fatal to the retention of the vacuum or economical exhaustion of the pipe. Were the valve to continue open, the atmospheric air would then be pumped into the pipe instead of the attenuation of the air within the pipe itself proceeding. When it is considered, too, that there must be an open slit, with a continuous valve, from end to end of the pipe, whether one mile or three miles, or from stationary engine to stationary engine, over any extent of a railway, the practical difficulty arising from leakage must at once be apparent. On the Dalkey line the length of pipe being only one and a quarter mile, it was apparent that in short distances like this, to erect air-pumping engines would be a strong objection to this system. It was therefore proposed when that railway was opened, that the fixed engines might be placed at every three miles, or, perhaps, a greater distance along a line, and an arrangement made by which, when the travelling piston approached the end of one range of pipe, the piston would open a transverse valve at the end of the next pipe, which would admit it into the

next length of pipe, or within the influence of another air-pump, and so on, from one range of exhausted air-pipe to another; and so over the length of railway a train might proceed without stopping. There are, perhaps, few inventions in these inventive times that display more mechanical skill in overcoming difficulties than the atmospheric mode of propulsion, so far even as it has yet been practically tried; and should it ultimately prove unsuccessful, it will be exceedingly mortifying that so much labour should have been bestowed in vain; but should the result of experience be, to prove the system defective, it will sink into desuetude like many other inventions, to which, perhaps, the mental powers of the contrivers have been self-devoted, and which now lie buried in the tomb of time.

LONDON AND CROYDON AND EPSOM, AND DIRECT PORTSMOUTH ATMOSPHERIC RAILWAY.

As this railway is modelled on the preceding one, and has attracted much public attention, and as I have had opportunities of observing its progress, I shall give a short description of it, avoiding technicalities. The atmospheric machinery

is designed under the patent of Messrs Clegg and Samuda, by whom, and Mr. B. Cubitt, the plan has been carried into effect. The portion of the railway completed is $4\frac{7}{8}$ miles, namely, from the Dartmouth Arms station, five miles from London, to Croydon. In the absence of practical experience it became necessary to fix the length of the tube in which the exhaustion could best be effected without loss of power. On the portion of the railway yet formed the stationary engine-houses, which are of the most tasteful design, have been erected about three miles apart; namely, at Dartmouth Arms, Norwood, and Croydon. A strong cast-iron pipe of 15 inches internal diameter, being the same size as that on the Dalkey line, has been laid down and secured to the ground midway between the lines of rails, which are 4 feet $8\frac{1}{2}$ inches gauge. The pipe is cast with iron bands to strengthen it, and is made in pieces of 10 feet, firmly joined together, and so forming a continuous air-tight tube. A partial vacuum is formed within this tube by pumping the air out with powerful force-pumps worked by the stationary engines, which are of 50 horse-power each, constructed specially for the purpose by Messrs. Maudsley and Field. The engine power is 300 horses for the $4\frac{7}{8}$ miles of rail, there being two

engines at each station. The exhausting cylinder or air-pump is about 6 feet 3 inches in diameter. The piston is worked by direct action of the engine. On the top of the cylinder there are 24 spring valves for the escape of the air drawn from the vacuum tube by the ascent of the piston, and a similar number permits the discharge of the air from the bottom of the cylinder on the descent of the stroke. The vacuum tube commences at one side of the cylinder, having a closing valve between the two.

The travelling piston is placed inside the main pipe, and fits it air-tight with leather packing, but free for motion. The piston is linked to the leading carriage of the train by means of a strong iron slanting plate or arm. The arm projects from the tube, through a continuous slit on its upper surface, and is fixed to the bottom of the carriage. The pressure of the atmosphere upon the piston forces it along, and carries with it the connecting arm, and with the latter the carriages are drawn onwards, their wheels gliding along the rails. The arm traverses the slit or narrow opening on the top of the pipe, from end to end, without any obstruction being offered to its progress. On the continuous slit in the pipe the valve is placed, extending the whole length of the pipe,

and upon the regulation of its action in opening and shutting, and being kept air-tight, depends the vacuum.

The external appearance of the valve is an immense range of iron flaps or plates, about eight inches long, connected together, placed in a square groove or continuous box in the top of the tube, and hinged at one side, as shown in *fig.* 61., being a perspective view of a portion of the vacuum pipe.

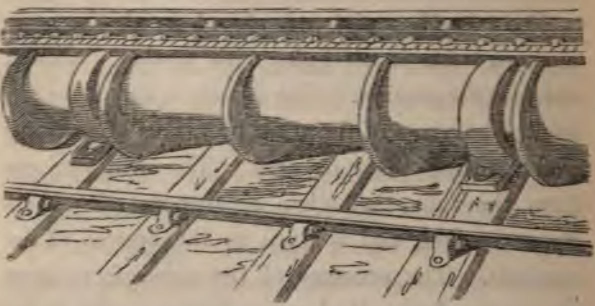


Fig. 61.

The valve is formed of a broad strip of leather rivetted between two iron plates. The upper plate seen being wider than the slit prevents the leather from being pressed into the pipe from the pressure of the atmosphere as the vacuum is formed. The lower plate fits the opening when

the valve is closed, and is curved to the shape of the pipe, preventing the air from passing the piston. The number of plates is requisite to give flexibility to the valve or flap. There is a thin plate of steel introduced between the leather and the upper plate, for the purpose of acting as a spring to close the valve after the piston has passed. One edge of the valve is securely held down by a succession of long iron rods bolted to a longitudinal rib cast on the pipe, on one side of the lateral opening, and the valves work on a hinge of leather similar to the valves commonly used in air-pumps. The opposite edge of the valve, when shut, rests on the other side of the lateral opening or slit of the pipe, having a margin cast on the pipe, thus forming a longitudinal channel or groove (*fig.* 62. B). This trough is filled with a composition of bees-wax and tallow, which, when it has been melted and cooled, adheres to the edge of the valve and keeps it air-tight: this substance becomes solid at the temperature of the atmosphere, and becomes fluid when heated a few degrees above it. As the valve must open continuately, or inch by inch, to permit the arm of the piston to pass, in a bed of the melting composition, one part of the apparatus, and not the least important, in the atmo-

spheric system, must obviously be the opening and cementing again of the valve as the train progresses, for as the valve must be raised and the cement broken on the approach of the bent connecting rod, so it requires to be again immediately closed. In order to effect this, four small wheels (*fig.* 63. E E) are fixed within the pipe behind the travelling piston (C), and travelling with it, two before the bent plate or connecting arm (*fig.* 62. F), and two behind it. These wheels are the means provided by which the one edge of the valve is raised, to permit the connecting rod freely to pass without touching or destroying the valve, and also for the admission of air. As the valve opens the air rushes into the pipe, on the back of the piston (*fig.* 63. C) equal to the area of the pipe, and thus the atmospheric pressure is kept up. This explains how the pressure of the air is made continuously operative on the piston within the pipe from which the air is exhausted. In order to re-seal the vacuum valve, as fast as the composition is broken in the trough, there are fixed to the carriage small steel wheels, regulated by springs: the leading wheel (*fig.* 64. C) passes light over the longitudinal valve, and is followed by a copper tube or heater (D), about five feet long, which

is attached to the under side of the carriage. The heater is filled with burning charcoal, and passes over and re-melts the composition, which when cold becomes solid, leaving and retaining the valve as air-tight as before, in readiness for the next train. The construction of the valve, its adaptation for the rapid passage of a connecting arm, and the apparatus for opening and

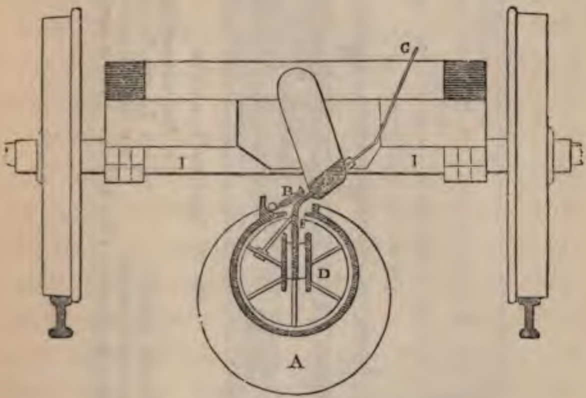


Fig. 62. Cross Section of the Tube, &c.

A Exterior section of the cast-iron pipe, which is made with projecting flanches, for strength; the interior circle shows the diameter of the piston within the pipe.
B The longitudinal valve open, showing the connection between the piston and the carriage.
D A valve in the piston which opens by lever G, which in case of accident, will allow the air to pass through the piston.
F Plate or arm connecting piston with carriage.
G The lever handle.
I I The axles of carriage.

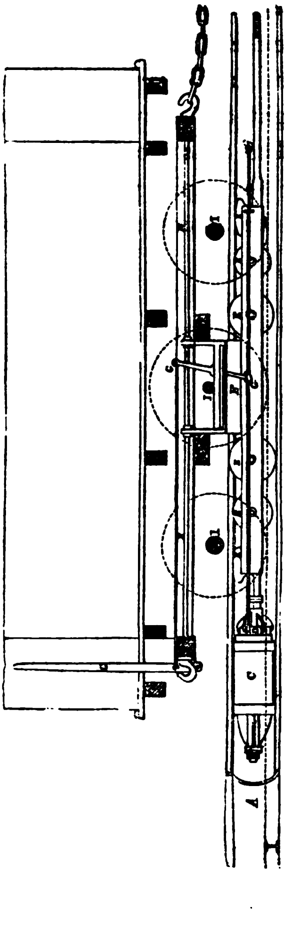


Fig. 68. Leading Carriage.

A Main pipe, or tube.
B Longitudinal valve (in cross section).
C Piston fitted with two capped leathers.
E E Wheels, &c. for raising longitudinal valve B.
F Arm connecting piston, &c. with carriage.
G G Levers, &c. for opening valve D in piston.
H H Draw bar of carriage.
I I I Axles of carriage wheels.

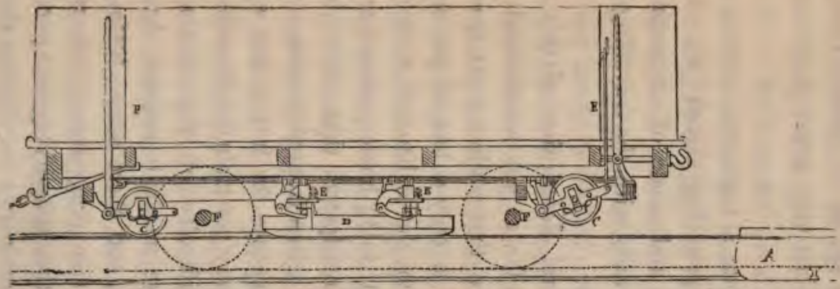


Fig. 64. SECOND CARRIAGE.

A Main pipe, or tube, with the longitudinal valve closed.

C C Closing wheels, which pass lightly over the longitudinal valve.

D Heater, for sealing valve (containing charcoal.)

E E Gear for raising or depressing closing wheels and heater when stopping.

F F Carriage axles.

sealing it, form the important points in the atmospheric railway system of Messrs. Clegg and Samuda, and display very great cleverness and ingenuity.

Fig. 62. represents a transverse section of the pipe shown in the preceding sketch (*fig.* 61.), the continuous valve, and mode of connecting the carriage upon the rails with the travelling piston within the pipe.

Such is a general description of this atmospheric railway, so far as yet constructed. Mr. Samuda has shown that while a great speed can be attained, there is only a loss of power from leakage of air into the exhausted tube of not more than from 1 to $1\frac{1}{2}$ horse-power per mile, whereas it was anticipated that much loss of power would have arisen from this cause. It has been stated the expense for lost power will not be more than a penny per train for 20 miles. In the mechanical difficulty of the opening and closing of the valve much, it appears, has now been accomplished, and there seems little doubt that as this invention progresses, means may be found for still farther simplifying and perfecting this part of the machinery; for the less the complication of the contrivance for this purpose the more likely it will be to prove successful.

Various accounts have been given as to the rate of speed attained in the trials made on this railway: the greatest speed is said to have been one mile in 62 seconds; or a speed, for a short distance, of 75 miles per hour. The result of a trial trip with 10 carriages of an estimated weight of 50 tons, from Dartmouth Arms to Croydon, the distance being, as already stated, about five miles, was lately published: the time occupied, including 1¼ minute consumed in advancing the train from the station to the opening of the vacuum tube, was 8¾ minutes, average speed at the rate of 35 miles per hour. The distance was run with the wind strong ahead: the greatest speed for a short distance was nearly 60 miles per hour. Average indication by the barometer of vacuum in the engine-house, 28 inches, in the carriage attached to the piston, 25 inches. By the trials made, the five miles of the tube were exhausted to the full extent, the average of the barometer being at the time 27¼ inches, while the piston traversed the whole length of the tube. Thus far the vindication of the atmospheric system, as respects its dynamic power at least, has been established.

The power of the atmospheric system in ascending stiff gradients has also been brought out;

for the new line crosses the Brighton line by a handsome viaduct, with an inclination rising 1 foot in 50, and a curve of half a mile radius, and these are taken with the atmospheric power with perfect ease. Indeed a train has been brought to a stand-still to deprive it of its previous impetus at the foot of the incline, and then propelled up the incline without difficulty.

The momentum given to the carriages by the atmospheric power is checked by means of powerful breaks: such has been the momentum acquired, that two pair of breaks were applied for $\frac{5}{8}$ths of a mile before stopping ensued. There is also a contrivance, a valve in the travelling piston, which was used in the experiments — by which the air, when desired, may be allowed to pass through it, and the vacuum, and consequently the force of propulsion, gradually decreased. It has also been projected that means should be devised for at once disconnecting the carriages from the travelling piston.

It would be quite impossible to describe or even notice the many contrivances proposed of late for atmospheric propulsion without filling volumes: but it would be out of place in this treatise to do so, as the object is to point out the progress which the railway system has practically attained, and

not to speculate on what inventions may ultimately be successful: hypothetical proposals are therefore avoided, and only those inventions which have been carried into effect described.

Mr. Henry Pinkus, whose name has already been noticed, has recently published an elaborate description of his patent atmospheric railway. Mr. Pinkus was amongst the first who had the merit of bringing the atmospheric system prominently before the public. He obtained patents for his inventions in 1834, 1836, and 1839. Several years ago he exhibited a working model of a small stationary engine, forming a vacuum in flexible tubes. In 1840, he published a pamphlet describing his "Agrarian system," or the pneumatic principle to effect the working of agricultural machinery.

Among other plans of atmospheric railways proposed, is that of Mr. James Pilbrow, of London, who obtained a patent for his invention on the 17th of May, 1844. Mr. Pilbrow appears to have founded the claim to superiority of his patent system upon what he considers the defects of Messrs. Clegg and Samuda's, such as the difficulty of getting a closure of the valve. He points out the advantages of his plan to be, the avoiding leakage by burying the pipe, and working the

apparatus without a valve, and the travelling piston, invented by preceding experimenters, is placed in the exhausted air tube, and is connected to the carriages by a small upright rod moving in an air-tight slit or groove on the top of the tube: the rod is kept in its track by guide wheels, and at certain distances small wheels are placed on the railway, which work in a rack attached to that travelling with the leading carriage. At the present stage, it is impossible to form any decided opinion of this contrivance. Whether the rod will slide in a slit sufficiently tight to prevent leakage without a great increase of friction, remains to be seen when practically tested on a public railway. Some new railways have been projected on this plan.

Amongst the numerous patents for the atmospheric principle of propulsion, is Mr. John Aitkin's, 1844. He proposes to fill the traction pipe with water, and, by long eduction pipes descending from the former, to obtain a vacuum; or to use water for covering the valve to retain the vacuum obtained. A patent was obtained by Mr. J. G. Shuttleworth, of Sheffield, in 1840, for the application of a column or body of water acting against a piston in a tube for the purpose of the propulsion of carriages. Water has likewise been

proposed in place of steam, as a more economical motive power to work the air-pumps of atmospheric railways, and in some districts of a country might be usefully employed, if this system of traction was adopted.

COMPRESSED AIR AND AIR ENGINES.

Mr. Nickel's system of atmospheric propulsion has lately been made public: he professes to work railway carriages without either longitudinal valves, racks, wheels, or pinions. His plan consists of a tube charged with compressed air in connection with a fixed engine, and the inflation of these tubes, pressing on smooth wheels turning on vertical spindles under the carriage, forces along the train with velocity.

Besides the direct action of atmospheric pressure upon a moveable piston, and the power of steam otherwise applied, a plan has been proposed of working engines with condensed air to propel railway trains: these are termed "Parsey's air engines."

The inventor of these engines, it appears, is sanguine enough to imagine that he has accomplished an object which will work a complete re-

volution in the mode of drawing or propelling trains on railroads, and in the manner in which the rotatory motion of paddle-wheels in ships is produced. Mr. Parsey's invention is, he thinks, applicable to all the purposes of setting machinery in motion for which steam-engines are now employed. The engines are worked by means of condensed air. The elasticity of air when compressed into receivers may be raised to any power. The engines, according to the description furnished by the patentee, can be filled at a terminus with highly condensed air, previously generated, and replenished from stationary receivers at the various stations of railroads as often as occasion may require. To the receiver or receivers of the engine so filled, to obviate the excessive force and gradual decline of pressure as the working cylinders draw it off, a receiver is attached, into which the air passes till it reaches a given working pressure, which it cannot exceed but by adjustment of the engineer, as the self-acting regulator belonging to the working receiver shuts or opens the inductive passage from the high-pressure receiver or receivers uniformly with the discharges from the driving cylinders, by which means as much power is carried by the engine as will propel it and a train any distance. It is stated that many

mechanicians and practical engineers have spoken of the model in high terms. Whether the plan will succeed or not must at present be uncertain, but its merits can only be ascertained by its being fully tested.

Carbonic acid gas and other gases have been tried, to produce a vacuum. Mr. J. Robinson, of London, has a patent for a mode of working engines by the agency of gas for producing motive power. Experiments have also been tried on railways to make use of electro-magnetism as the motive power, but, as yet, with little prospect of success.

THE COMPARATIVE ADVANTAGES OF THE ATMOSPHERIC AND LOCOMOTIVE SYSTEMS.

At the present time, when so many railways are proposed, and as, from the advantages derived from this mode of transit, it must be apparent that, in order to place one district of the country on a footing with another, every town and village must have the means afforded of rapid and direct communication, otherwise certain localities must be placed beyond the pale of easy access, it is most important to know, so far as experience

has yet gone, the views of scientific men as to the comparative advantages of these modes of traction.

The atmospheric railway system has already been fully discussed at meetings of the Institution of Civil Engineers, and the most eminent of that body appear to take opposite views respecting the antagonist powers. In a communication made to the Institution by Mr. P. W. Barlow, C. E., "On the comparative Advantages of the Atmospheric Railway System," he gives the result of certain experiments on the Tyler inclined plane of the Canterbury and Whitstable railway, showing the amount of lost power of the rope traction as compared with that of the atmospheric railway system on the Dalkey inclined plane, from which it appears that a stationary engine of twenty-five horse power will convey thirty-five tons at an average speed of seven and a half miles per hour up the former incline of 1 in 48, and is capable of producing as great a useful mechanical effort as the engine of 100 horse power on the Dalkey line, as the former raises more than half the load three times the altitude on the same length of an incline in nearly the same interval of time: or, in other words, trains of thirty-five tons are raised by a 25 horse power engine on an incline of 1 in 48 at the same speed as the Dalkey engine of 100

horse power raises trains of sixty-six tons on an incline of 1 in 138: that the lost power on the Whitstable incline averaged four-tenths of the whole power, and on the Dalkey line it averaged eight-tenths of the whole power: that the loss in transmitting the power to the train, as shown in Mr. Samuda's experiments, exceeds eight-tenths of the whole power: that the effect of the increased leakage at the higher degrees of the vacuum does not exceed the increased resistance of the air, and thereby proves that the leakage is not the main source of lost power.

With heavy loads and a high vacuum, the power of the engine required to form the vacuum will amount to the greater proportion of the whole power exerted, and which will be practically lost. With the other extreme of light loads and a small vacuum, the friction of the air in the pipe becomes an equally large proportion of the power expended; because the whole bulk of the air must be exhausted, however small the load may be: so that there will be one particular vacuum and load with any given engine and pipe, in which the sum of these losses will become the least possible. But whatever this may be, it is evident the amount must be fatal to the atmospheric system as a mode of applying stationary

power: that there is also a loss of power necessarily arising from the construction of the air-pump, and, in addition to that from leakage, there will be a certain loss, from the atmosphere not having time to act with full effect on the piston: that as the loss from leakage does not form a large proportion of the lost power, there is little field for mechanical improvement, which has been urged as an argument in favour of the system: that the loss of time and power, from the interval necessary to get up the required vacuum, will have the effect of reducing the average rate of travelling on a single line of atmospheric pipe considerably below that of a locomotive line, because such loss of time must occur at the meeting of every train; and with trains running at intervals of half an hour, this delay must necessarily occur every quarter of an hour.

The preceding is the substance of Mr. P. W. Barlow's interesting paper, which does not augur very favourably for the permanent success of the atmospheric mode of traction. He states the best result obtained from the experiments on the Dalkey line, was the transport of trains of thirty tons in five minutes. It has been ascertained, that the atmospheric system on the Dalkey line has

not been remunerative, having hardly paid its working expenses: this should not, however, be imputed to the system, for it may have arisen from the locality and nature of the traffic, and the system will soon be more fully developed on the London and Croydon Railway. Even should this system be less efficient as a moving power than stationary engines with the rope traction, it is more convenient, and gets rid of the tear and wear of ropes.

With respect to the supposed superior safety of the atmospheric system, there has not yet been sufficient experience of the working of it on an extensive scale to judge. One very obvious defect which appertains to the atmospheric as well as to all systems of traction where the motive power is entirely separated from the carriage is, that no possible control exists over it. Where fixed engines were used for rope traction, it has been long found to be attended with practical inconvenience; and it does not appear how it can be lessened by the atmospheric plan. Any obstruction on a line is just as apt to be run into by the atmospheric carriage as by the locomotive, and the carriages may thus be overturned, while in reality less power exists in slowing or checking the atmospheric carriages than in the locomotive.

Supposing the momentum in either train, proceeding at sixty miles an hour, to be the same, the locomotive has the advantage of having the means of at once reversing the action of the engine, and cutting off the supply of steam; and even should the atmospheric train be placed in the position of disconnecting the carriage from the piston, still, as has been remarked, while the locomotive has the power of lessening the severity of the shock from any obstacle on the rails, the atmospheric must be nearly powerless to avoid destruction. Although, therefore, the atmospheric plan has apparently an advantage in rendering direct collisions barely possible, as two trains cannot move in the same section of pipe at the same time, and one must leave the section of the pipe that it may again be exhausted of air, still, until experience has fully developed the safety of the working of the system, it is merely hypothetical to speak of its entire safety. With respect to the relative expense of the atmospheric and locomotive systems, I hold this to be of much less importance than the matter of safety. It becomes, indeed, a matter of calculation, of easy solution, whether fifty horse or more power applied to work an air-pump, or the same power

applied directly to propel a locomotive, is the most effective.

There is one thing certain, the atmospheric system cannot be proved more convenient and economical than the locomotive system, and it should at least, if it is to have a preference, be proved to be better adapted for the public safety. But with respect to the additional safety arising from tying down the carriage on the centre of the line, the questions suggest themselves, Will the carriage be tied down when passing over points and crossings, where there exists the chief liability of running off? and is not the chance of collision at sidings which are worked by momentum greater than where there is a control of a locomotive, and are not these the places where the greatest liability of collisions exists? The power of stopping a train is considered by some greater on an atmospheric than on a locomotive line; but if the power of stopping, as well as the momentum, increases with the gravity, no advantage can be gained in this respect, for by removing the engine and tender, the weight which is most concentrated, and therefore most economically and efficiently applied, is removed. But suppose it is granted that the atmospheric is less liable to accidents from collision than the

locomotive line, will not the great expense of formation and working the line necessarily confine the construction of this railway system to single lines of way? There is no doubt that the atmospheric on a single line is considerably safer than a locomotive on a single line, which is not safe; but locomotive single lines are, however, rarely used. Although it has been held by the advocates of the atmospheric system that it possesses the peculiar advantage that a single line would prove sufficient; yet, because on the very few miles of single rails where locomotive power is used few accidents have happened, is there any person who would recommend such a mode of railway on lines where great traffic exists? The idea, therefore, of holding out that the atmospheric possesses this peculiar advantage, is merely visionary. Mr. R. Stephenson has shown in his report the impracticability of working a single line of atmospheric railway when applied to a line of 112 miles in length with trains running every half hour and at a mean velocity of thirty miles an hour, by the fact that "the total time of the journey would be increased ten hours!" in consequence of the delays occasioned by one train waiting till it had met with that which was coming in the opposite direction, and the pipe was exhausted so that it

could proceed. On shorter lines, perhaps, these obstructions would not be so objectionable; but, as has been remarked, "would it not be as easy for locomotives to follow each other with trains every half or quarter of an hour, and when arrived at a station, to wait till the train in the opposite direction had passed?" But where is the engineer who would recommend the adoption of such a system if he were held responsible for the regular working of it?

Numerous objections have been urged against the working of the atmospheric principle; such as the uncertainty of working the traffic both on "terminal and intermediate stations, and the necessary arrangements at level crossings." At terminal and intermediate stations, where goods and mineral traffic is large, some other power would be required to be employed than that of the main line. The waggons are now shunted or backed into a siding by the engine; but in atmospheric lines manual, horse, or engine power must be employed to remove the waggons; and this must add to the risk of accident, from their being left probably for a time on the main line. Another objection will arise from the loss of power by the uncertainty at starting of the weight of the train; and to maintain a higher velocity than with the

locomotive system, engines of greater power must be used, or about 200 horse power for every mile and a quarter. Or, as the leakage or rush of air into the exhausted pipe, which influences the velocity of the trains, will be greatly increased by extending the length of the pipe to three or four miles, the power required to work it must be proportionably augmented. This extension of power may have the effect, that the expense must be so increased to attain the same power as with the locomotive system as to make the cost inordinate. Such are some of the chief objections urged against the atmospheric system, to which may be added, that the derangement of the engine of one station may stop the traffic of the whole line. Much has been said in favour of the atmospheric system, on the ground of the absence of smoke and dust, and also that cinders are not scattered about as by the locomotive engines; and doubtless this is a great advantage, if not counterbalanced by other drawbacks.

With respect to the expense of working the atmospheric system, different opinions obtain. There seems little doubt that to be effective, the power of the engine must be large and a surplus power always at command. On the London and Croydon railway, in the five miles, the 300 horse

power erected has been estimated at 15,000*l.*; and should the supposition be made, that one locomotive engine was provided for every mile of railway, the five engines would cost, at 1500*l.* each, only 8000*l.*; thus leaving a balance of 7000*l.* on this head against the atmospheric. Some have taken a very opposite view to this of the comparative expense of the two systems. One writer states that, supposing a railway of 30 miles required ten fixed engines and pumps, the cost of this would only be 42,000*l.*, with an annual expense to uphold them of 10,320*l.*; whereas the locomotive department of the Liverpool and Manchester would cost three times that sum. There, however, does not appear sufficient data established to come to any correct opinion on these points. Mr. Pinkus and Mr. Pilbrow hold out in their statements a much cheaper mode of construction.

It has been observed by Mr. Berkeley, C. E., that the mechanical difficulties in the application of the atmospheric system are, perhaps, the least important for consideration, as it may be assumed that the experience and ingenuity of mechanics, where they exist, will overcome them. But surely no system can be efficient where real difficulties in its practical working exist; and until these are

entirely overcome it cannot be deemed perfect. However clever the present arrangements of Messrs. Clegg and Samuda's system are, and however perfect the workmanship may be, still wheels revolving at a rapid rate within a lengthened tube must be liable to occasional derangement, and require constant watching, and it has been shown that the opening and closing of the valve depends on this agency. Out of the numerous inventions one perfect one may be obtained. It is only by the practical working of the system which Messrs. Clegg and Samuda have introduced that will be ascertained wherein lies the defect, and its correction found out. From the momentum of the carriages, their lightness on the rails, and the difficulty of making a break act quickly on them, the danger must be as great, if not greater, of the hind carriages running off the rails than with the locomotive train, and of their being crushed in a similar way; for it cannot be the single slight attachment of one carriage in a train to the arm of the travelling piston that will guard against such a casualty. One of the strongest arguments urged in favour of the system seems to be the capability of ascending steep gradients; but this cannot either be deemed with rapid velocity as either advantageous, prudent, or

safe; beside which, much has been done, even in this respect, with locomotive engines.

Having thus considered the question of the locomotive and the atmospheric system, it must be left to the result of time to test their comparative advantages, for, at the present time, the accounts of the latter are conflicting and contradictory.

IMPERFECTIONS OF THE LOCOMOTIVE RAILWAY SYSTEM.

In making a few brief observations under this head, I feel that to find fault with a system which has been the growth of a few recent years, and which has already accomplished so much, is ungracious: the remarks are made with the view of endeavouring to bring about a similarity of railway practice so essential as respects the safety of passengers, and important for the interest of the railway companies.

The chief defect of the locomotive railway system arises from the want of uniform and fixed data founded upon properly conducted experiments to regulate the construction of railways — as to the gradients, curves, height of tunnels

width of viaducts, form of rails, and mode of fixing these; the width or gauge of the rails, the limit also of the railway between embankments, elevation of bridges, road crossings, and the various points of railway formation in which so much discrepancy in practice arises. No general rule seems adopted on almost any point. Of course it is not desirable that, in minor matters, opinions should not differ and the plan be adopted best calculated for the circumstances; but, where the arrangement involves the public safety, it seems desirable that in all the leading features of railway practice, a similarity of system should be worked out: on the contrary, it has been shown that, on one railway, one form of iron rails, chairs, and sleepers exist, and, on another, one totally opposite; and so on with other points on which different views are entertained,—all tending to perplex and to prove a fruitful source of accidents, the usual concomitants of uncertainty. The effect of this has been to weaken public confidence in the system, and has led to the development of those schemes of atmospheric propulsion, some of which have been noticed.

QUESTION OF THE BROAD AND NARROW GAUGES CONSIDERED.

One of the most important of the points upon which discordance of opinion exists is the railway gauge. I have already shown that the great preponderance of the railways formed in this country have been constructed with the narrow gauge; — not, seemingly, from any conviction of its superiority or advantages, but most probably from the circumstance that it was the gauge adopted on the earlier lines of railway; and it was more convenient to assimilate the gauge of the railway to be made to that of those in the vicinity, than to adopt a new gauge; for although, in the first instance, the railway may have been unconnected, the opportunity might occur to form a junction. It is probable some such reason influenced the adoption of the narrow gauge; for it cannot be supposed, in the railways from the period of the opening of the Liverpool and Manchester Railway, till the formation of the

Great Western, that any real conviction existed, or any positive knowledge had been acquired, that the 4 feet 8½ inch gauge was the best which could have been adopted. The narrow gauge had been at first used; and, therefore, as it seemingly presented no practical inconvenience, it became gradually extended over the kingdom. In the recent discussions of this question, there is brought out, prominently, the advantage which would have been derived by establishing a uniform railway gauge over the United Kingdom. Had this point been taken cognizance of by government when the Liverpool and Manchester line was opened, and had a uniformity of gauge been then adopted, much confusion would have been avoided; for it seems more than probable that, sooner or later, at least on all the direct lines of communication through the country, the same gauge will be established, so as locomotive carriages may run without interruption from one extreme of the island to the other.

Up to the present time, convenience, economy, and the views of the Company, determine the adoption of the broad or narrow gauge.

It is to be regretted that, as personal interests are so mixed up with the important question of the gauge, it is hardly possible to expect, at the

present time, an impartial solution of it. There can be no doubt that a railway with a gauge of 4 feet $8\frac{1}{2}$ inches can be made at much less expense than with a 7 feet gauge. As respects the first cost, if the question is dependent on this, it may be viewed as settled. But although the proportion of the broad-gauge railways is only as 1 to $5\frac{3}{4}$ of the narrow yet formed, and perhaps a greater disproportion exists in those projected, still, if the principle which Mr. I. K. Brunel adopted is the correct one, sooner or later his views may come to be adopted, and the broad gauge extended.

It may, indeed, seem a great hardship and a useless expense, and in many cases impossible to convert the narrow into the broad gauge, although it is a simple thing to alter the broad to the narrow, as it would require, in the former, widening of embankments and enlarging of tunnels and bridges, all of which things would occasion a greater outlay than railway companies can reasonably be expected to agree to; it is, therefore, the more imperative that no dubiety exist as to the real advantages of the broad gauge. It has, indeed, been very naturally supposed that in this mechanical age some scheme

will be devised to get over the difficulty of having recourse to altering the gauges of existing railways, to adapt them to each other. Several suggestions have been made and plans devised to attain this object, and already has an ingenious apparatus been tried at the Paddington station of the Great Western, by means of which it is stated that thirty or forty trucks or waggons, containing 30 or 40 tons, can be removed from the narrow to the broad gauge, or *vice versâ*, in about six minutes.

What the public are most interested in, in the discussion of the merits of the gauges, is the safety and comfort of railway travelling; and that doubt should hang round a point which should not be of difficult solution, does not add to the confidence in this mode of transit.

The opinion in favour of the broad gauge of 7 feet is founded on various reasons; amongst others, that additional speed with greater safety is attained; that there is a decrease of friction by enlarging the diameter of the wheels; that there is afforded room for broader trucks, better adapted for many kinds of goods, and that there is also afforded a larger space for the machinery, and room for a larger boiler with a greater extent of fire-box surface. From the great generating sur-

face for raising steam more water is evaporated, and the motive power proportionably increased. So much so is this the case, that by recent improvements on the Great Western line, its supporters estimate that the express trains will be enabled to carry 300 passengers or 120 to 130 tons, at the rate of 65 to 70 miles per hour. Another advantage of the broad gauge, an important one, is, that greater stability is given to the carriages by keeping down the centre of gravity, from the body being inside of the wheels.

The objections to the wide gauge are founded on the greater cost of the railway, as also of the engines and carriages, the additional weight on the rails, and the additional friction on the curves. The reasons given by Mr. Brunel are stated to be fallacious, namely, that the narrow gauge is dangerous at high speed, and that it does not afford scope for the powerful machinery necessary for locomotives to attain high velocities, while by increasing the gauge he should be able to use higher wheels to lessen the friction; but Mr. Brunel has abandoned the high wheels for carriages he first used, and reduced them to the reasonable dimensions of 6½ to 7 feet diameter; and the other reasons, whatever force they may have first

had, no longer exist. The supporters of the narrow gauge state, that by the improvements which have been introduced, namely, increasing the length of the boiler and generating more steam with the same fuel, the simplification given to the working gear, and the improvements lately made on the valves and expansive apparatus, means are provided for economising steam faster than it is required; and that as an engine can go at a velocity of upwards of 60 miles an hour with a wheel of 5½ feet diameter on a level, and nearly the same on a moderate incline, on a gauge of 56½ inches, and that as it is equally safe as respects accidents as the broad gauge — what real advantage can be derived from making the change?

Thus we perceive the advocates of each gauge are at no loss for arguments to support their rival claims for public approbation.

Whatever may be the opinion of different engineers as to the preference they give to the narrow over the broad gauge, it appears, so far as can be judged of, that the public feeling is in favour of the broad gauge. Although many think it is best to let well alone, and wait for more experience as the safest test, yet procrastinating a decision of this point can be productive of

nothing but inconvenience, and we have already seen how many years in railway advancement were lost in foolish assumptions which a few experiments could have speedily tested; and surely it is time that a point so important as the best gauge of rails for public safety should be placed beyond cavil.

Perhaps the main objections to the broad gauge arise on the ground of increased expense in the first construction, and the fear of being forced, from circumstances, to tear up existing rails; for all statements promulgated as to the inferior stability of carriages on the broad gauge, and danger from their axles breaking, are properly considered fallacious. But objections arising against altering existing railways cannot apply to the numerous projected lines before Parliament.

As the Act passed in favour of the line from Oxford to Wolverhampton carried the broad gauge into the heart of England, the railway companies took the alarm, and much discussion took place on the question of the gauges. A statement was issued by those connected with the narrow gauge, to the effect that the mixture of gauges would be attended with two great public evils; the one arising from the change of passen-

gers and goods from a line of one gauge to that of the other; the second from the increased cost consequent upon the formation, in many cases, of two lines of railway, where one would have answered the purpose.

Parliament, during the session of 1845, having expressed no opinion in favour of the broad gauge, as the same doubt and uncertainty still hung over the subject, a royal commission was appointed by government on the 5th of July, 1845, to inquire into the question,—whether, in future Acts of Parliament for the construction of railways, provision ought not to be made for securing a uniform gauge, and whether it would be expedient and practicable to take measures to bring the railways already constructed, or in progress of construction, in Great Britain, into uniformity of gauge.

It must now be matter of regret that this question had not long ago been taken up by government, as it seems self-obvious that the uniformity of gauge would not only be of great utility in the United Kingdom, but throughout Europe.

The opinion of this commission, if founded on sure evidence or well-conducted experiments, will be of essential service in affording uniform

data to go by in the planning of railways. Besides the broad and narrow, it has been previously stated, that the Irish commissioners recommended a gauge of 6 feet 2 inches, not widening the carriages, but making the wheels outside the bodies: this gauge has been adopted in Ireland, as also a gauge of 5 feet 6 inches. To establish a third railway gauge in Britain, however desirable it might have been at one time, would now be attended with much practical inconvenience. Still, however, if such a gauge is really the best for the permanent interest of the public, no inconvenience should weigh against public safety. Mr. John Miller, C. E., a gentleman of great experience in railway engineering, in his evidence before the Committee of the House of Commons on the Oxford, Worcester, and Wolverhampton Railway, stated his opinion to be, that he considered a medium gauge of 5 feet 6 inches as the preferable one. Other engineers have considered a gauge of 7 feet not too broad. But if Mr. Brunel's gauge, namely 7 feet, be found to be too broad, and 4 feet 8½ inches too narrow, in all future trunk lines of railway, a gauge of 6 feet might be adopted, and means might be found of working the present lines in existence without material alteration. A gauge of 6 feet, surely, cannot be deemed

too broad, when we find the body of a carriage 5 or 6 feet wide, and 9 feet high, weighing 4 tons, resting on so narrow a base as 56½ inches. There can be little doubt entertained that the choice of the narrow gauge originally was inconsiderate, for when a broad machine, with a comparatively high centre of gravity, is placed on a narrow basis, a certain degree of danger must arise of its oversetting, at high speeds, even on a straight line, by the accidental sinking of the rail, and more so from its oscillation on sharp curves, which exist on many railways. It may be fairly presumed, that many of the new lines now in progress have been forced into the adoption of a gauge of 56½ inches, perhaps against the wishes of the engineer, simply because they are to be connected with other lines of a similar gauge.

It would perhaps have been more advantageous for the public interest had the powers of the commission appointed by government been extended further; for not only is the question of the railway gauge environed with doubt and uncertainty, but almost every other point connected with railway construction. We find, even the other day, one engineer recommending single line railways with steep gradients as the safest — a plan which other engineers and committees in

Parliament condemn. The question of gradients, curves, and even the form of, and manner of laying rails, has not yet been fully determined.

Since the preceding observations were in type, the report of the Gauge Commissioners has been presented to Parliament. It is a very able document, and appears to have fully considered the arguments on both sides. That it could not give satisfaction to opposing parties may be readily surmised. If the conclusions are therefore different from what, by some, were expected, it cannot be imputed to prejudice, or any undue partiality.

The following is a summary of it: —

The Commissioners state in the outset that,

I. Their attention was first directed to ascertain whether the break of gauge could be justly considered as an inconvenience of so much importance as to demand the interference of the legislature.

They divide this subject into four heads.

1st. As applying to fast or express trains.

They believe that the inconvenience produced by the break of gauge will, in some respects, be felt less in these than in other trains, and do not consider the inconvenience of so great a nature as to call for any legislative measures, either for its removal or mitigation.

2d. Ordinary or mixed trains.

They arrive at the conclusion that the break of gauge would inflict considerable inconvenience on travellers by the trains now under consideration, and that this incon-

venience would be much increased at points of convergence of more than two lines. The change of carriages, horse-boxes, and trucks of an entire laden train would be a serious inconvenience during the day, and at night would be an intolerable evil; therefore, legislative interference is called for, to remove or mitigate such an evil.

3d. Goods trains.

The Commissioners are of opinion, that a break of the gauge would altogether prevent the transfer of articles of machinery; and that with respect to goods, minerals, agricultural produce, cattle, &c., it would create serious inconvenience.

4th. Conveyance of troops.

They are of opinion that the effect of a break of gauge might expose the country to serious danger.

On the whole, they sum up their conclusions by stating that they consider a break of gauge a very serious evil.

II. The second stage of their enquiry is, to discover the means of obviating or mitigating the evil which they find to result from the break of gauge. After enumerating the several mechanical plans which have been suggested, viz. 1. telescopic axles, an arrangement for the wheels to slide on the axle so as to contract or extend the interval between them; 2. a form of truck adapted to the broad gauge, but having a narrow rail on its upper surface; 3. a method of shifting the bodies of carriages from a platform and wheels of one gauge to that of another; 4. a proposal to carry goods in loose boxes which may be shifted from one truck to another, the Commissioners state their belief, that no method has been proposed to them which is calculated to remedy, in any important degree, the inconvenience attending a break of gauge.

III. The Commissioners next view the subject with reference to the general policy of the country, involving safety, accommodation, and convenience for passengers

and goods, speed, and economy. Upon these various points, they enter with great minuteness, and sum up as follows: —

"1. That as regards the safety, accommodation, and convenience of the passengers, no decided preference is due to either gauge, but that on the broad gauge the motion is generally more easy at high velocities.

"2. That in respect of speed, we consider the advantages are with the broad gauge, but we think the public safety would be endangered in employing the greater capabilities of the broad gauge much beyond their present use, except on roads more consolidated and more substantially and perfectly formed, than those of the existing lines.

"3. That in the commercial case of the transport of goods, we believe the narrow gauge to possess the greater convenience, and to be the more suited to the general traffic of the country.

"4. That the broad gauge involves the greater outlay, and that we have not been able to discover either in the maintenance of way, in the cost of locomotive power, or in the other annual expenses, any adequate reduction to compensate for the additional first cost.

"Therefore, esteeming the importance of the highest speed on express trains for the accommodation of a comparatively small number of persons, however desirable that may be to them, is of far less moment than affording increased convenience to the general commercial traffic of the country, we are inclined to consider the narrow gauge as that which should be preferred for general convenience; and, therefore, if it were imperative to produce uniformity, we should recommend that uniformity to be produced by an alteration of the broad to the narrow gauge, more especially when we take into consideration that the extent of the former at present in work is only 274 miles, while that of the latter is not less then 1901 miles; and that the

alteration of the former to the latter, even if of equal length, would be the less costly as well as the less difficult operation."

The Commissioners guard themselves against expressing an opinion in favour of the narrow gauge of four feet eight and a half inches, as in all respects the most suited for the general objects of the country. But, on the whole, they submit the following recommendations: —

"1. That the gauge of four feet eight inches and a half be declared by the legislature to be the gauge to be used in all public railways now under construction, or hereafter to be constructed, in Great Britain.

"2. That, unless by the consent of the legislature, it should not be permitted by the directors of any railway company to alter the gauge of such railway.

"3. That, in order to complete the general chain of narrow gauge communication from the north of England to the southern coast, any suitable measure should be promoted to form a narrow gauge link from Oxford to Reading, and thence to Basingstoke, or by any shorter route connecting the proposed Rugby and Oxford line with the South-Western Railway.

"4. That as any junction to be formed with a broad gauge line would involve a break of gauge, provided our first recommendation be adopted, great commercial convenience would be obtained by reducing the gauge of the present broad gauge lines to the narrow gauge of four feet eight inches and a half; and we, therefore, think it desirable that some equitable means should be found of producing such entire uniformity of gauge, or of adopting such other course as would admit of the narrow gauge carriages passing, without interruption or danger, along the broad gauge lines."

The report is signed by "J. M. Frederic Smith, Lieut. Col., R. E.," "G. B. Airy, Astronomer Royal," and "Peter Barlow."

The report admits, what has been long believed, that the advantage of high velocity and ease of motion is with the broad gauge; that the driving wheels with it admit of greater diameter, which is favourable to high speed; and that a greater evaporating power can be given to the boiler without its undue elongation; while with the narrow gauge, the increase of evaporating power cannot be got without the elongation of the boiler, or raising its centre of gravity, both of which are dangerous at high speeds. Or should the power be increased by placing the cylinders of the engine outside the framing, it tends to produce at high velocities a rocking and irregular motion of the engine.

The Commissioners remark, "that the result has been, that we are fully satisfied that the average speed on the Great Western, both by express trains and by the ordinary trains, exceeds the highest speed of similar trains on any of the narrow gauge lines." From experiments made, the average speed of a train of 80 tons, exclusive of engine and tender, on the Great Western, was found to be 47·5 miles per hour. On the narrow gauge the speed was less, and when attempting a high velocity the engine ran off the rails.

Notwithstanding that the report appears to be in favour of the broad gauge, except for the conveyance of goods, the Commissioners recommend that, in future, all railways be constructed of the narrow. This conclusion is, no doubt, come to merely on the ground of the convenience of having a uniformity of gauge. They likewise remark, "as regards the safety of the passengers, no preference is due with well-proportioned engines except at high velocities, when we think the preference is due to the broad gauge."

It is thus admitted that for passenger traffic the advantage lies with the broad gauge; for although high velocities must be deprecated as endangering public safety, if carried to an undue excess, especially on lines where the railway is not of sufficient substantiality to bear it, still as rapid travelling is a desideratum by many, if kept within prudential limits, it must be an object if it can be combined with perfect safety. The preferable gauge must therefore be the broad one, "where the motion is generally more easy at high velocities," and where no necessity exists of overforcing or taxing ingenuity to give power to machinery when there is not space to place it. With the public mind the question of the gauge

will still be very much where it was. It might have been useful, had the point been more fully considered in the report, as to the practicability of converting the narrow into the broad gauge, or establishing an intermediate one.

The following among other appendices are subjoined to "the Report," seemingly, to show that by excessive speed accidents will occur on both gauges.

Statement of Accidents abstracted from the Reports of the Railway Department of the Board of Trade, in which the Engine and Carriages, or some part of the Train, have run off the Line, without any known obstruction, from September, 1840, to March, 1845.

Date of Accident.	Name of Railway.	Breadth of Gauge.	Deaths and Injuries.		Nature and Cause of the Accident.
			Killed.	Injured.	
		Ft. In.			
1840.					
Oct. 19	Eastern Counties	5 0	4	6	Excessive speed.
Nov. 8	Midland Counties	4 8½	...	8	Excessive speed.
1841.					
Sept. 7	Great Western -	7 0	1	...	One engine out of two off the line.
Oct. 2	London and Brighton.	4 8½	4	2	Bad road and excessive speed.
1843.					
Nov. 15	South-Eastern -	4 8½	...	...	Cause not known.
1844.					
Oct. 31	Newcastle and Carlisle.	4 8½	...	1	Excessive speed.

Similar Accidents which have occurred since the last Report of the Board of Trade, from March, 1845, to the 1st of January, 1846.

Date of Accident.	Name of Railway.	Breadth of Gauge.	Deaths and Injuries.		Nature and Cause of the Accident.
			Killed.	Injured.	
		Ft. In.			
1845. June 16	Great Western -	7 0	...	several	Express train-carriages only off the line.
June	Great Western -	7 0	...	...	Ditto, a similar accident, not reported.
Aug. 4	Northern and Eastern.	4 8½	2	several	Cause not ascertained.
Aug. 19	Northern and Eastern.	4 8½	...	2	Supposed cause, a defective joint. Less speed recommended.
Aug. 18	Manchester and Leeds.	4 8½	...	several	Express trains thrown over an embankment.
Dec.	Norfolk - -	4 8½			
1846. Jan.	York and Darlington.	4 8½	2	3	Experimental train —speed 48 miles.

DIFFERENCE OF OPINION AS TO GRADIENTS.

That the uncertainty which hangs round many of these points should lead to expensive alterations need not excite surprise, and that accidents should spring from such causes is equally apparent. Even the datum * of a railway section is

* The datum is the horizontal line in a railway section, from which the heights or depths of the places are measured, and to which all levels refer: by the Standing Orders the datum must refer to some fixed mark.

not defined, some engineers considering it desirable that one datum should be fixed for all railways in Britain, while in practice it is not so.

It has been seen that the invention and perfecting of the locomotive engine was a work of time. After the maturity locomotive travelling has reached, one can hardly doubt that, with so powerful and controllable a motar, the safety on railways will be much greater than it has been. One thing seems apparent, that the use of locomotive engines cannot now be objected to from the want of sufficient power. It has, indeed, been well remarked, that with steam as a moving power, the quantity of work to be performed need never be diminished, as the performance of it can always be effected by augmenting the power of the engine, provided the works are so substantial as to bear it; and this result has been fully verified in the history of the locomotive engine, as it has been shown that the rails have been increased from 50 lb. even to 85 lb. per yard. It has been shown that the old rule, which but a few years ago obtained, that a gradient of more than 1 in 105 could not be profitably worked except by stationary engines is a fallacy, for such has been the success from the recent — practical, not theoretical — improvements made in locomo-

tive engines to adapt them to ascend steep gradients, that it is probable it may lead to material changes in railway construction. If a gradient of 1 in 37 can be overcome, one of 1 in 75 cannot now present much engineering difficulty. It has, indeed, been considered possible, by the increase of power given to locomotives, and by improvements in their construction, to enable them to ascend steep inclines, in many cases, to avoid tunnels, viaducts, and other expensive earth works, which so much increase the first cost of railways. Whatever may come of the contemplated saving, there is evidence sufficient to show that engineers do not now hesitate to adopt steeper gradients than formerly to overcome physical obstacles. This idea has been adopted by the engineer of the Caledonian Railway, who stated in evidence that he gave a preference to a straight line, with steep gradients, to a curved line, with better gradients. On this line, now in course of formation, there is an incline, rising 1 foot in 75, and 1 in 100, for 9 miles between Beatock and Evan Waterfoot, — 5 miles of which is 1 in 75. By reference, likewise, to many Railway Acts, and prospectuses of projected lines, inclines of 1 in 70 to 1 in 80 in the line of way will be found, and steeper inclines for short distances. The

former class of gradients is to be worked with or without assistant engines; the latter with special engines. On the Beatock incline, from the length, an assistant locomotive engine is to be maintained. Nothing, however, shows more the uncertainty which surrounds the subject of railway engineering than the opposite opinions entertained. It is remarked by one engineer that he sees no reason why, in many cases, hydraulic locks should not be used to do away with inclined planes altogether. The same idea, several years previously, is given by another writer; namely, that a train might be changed from one level to another upon a platform raised by machinery;—a plan which has lately been proposed for another purpose, that of overcoming the obstacle of different gauges of rails.

Whether the proposal to do away with inclined planes or to overcome steep gradients on railways by increase of the tractive force, is to be successful, time can only tell; but so far as has been accomplished with the locomotive principle, there does not appear any valid reason for superseding it on this ground by the atmospheric system. The success attending the applications of the locomotive engine for steep gradients has, of late, led to very sanguine views being entertained of

greater improvements yet to be made on it. Beyond a certain angle and rate of speed they never can go with safety, and even in ascending the angle they can now do, there is, as one writer expresses it, such a development of asthmatic symptoms as to satisfy any one of the strain and loss of power undergone. To be satisfied with the application of the impelling power to ascend moderate gradients seems the best plan; for even were steep gradients easily ascended, they must be with risk descended. Extreme gradients obviously involve much danger in traversing them, and nothing but the result of ample experience will satisfy any prudent person, so far as is yet known, that in railway formation, be the cost of works what it may, moderate gradients should be dispensed with. If, by the substitution of powerful locomotives, tunnels, viaducts, and quick curves can in any degree be done away with, an object of importance is gained. While, however, duly appreciating the skill displayed by which steeps of considerable altitude are climbed, it must not be overlooked that the triumph of railway engineering lies in good gradients, and that every departure from the level is attended with a certain loss of power.

CAUSES OF RAILWAY ACCIDENTS.

From the rapidity with which railways have been extended since 1830, there has hardly been left sufficient time for matured experience to perfect details. The numerous and fatal accidents which have happened with locomotive engines were supposed to be necessarily attendant on the infancy of the system, and as more experience was acquired in it, it was presumed, they would be got the better of; but their continuance has created well-grounded alarm as to the efficiency of the system itself, and led, as we have seen, to the consideration if a safer method of traction could not be substituted. The absurdity of the advocacy adopted by its sanguine supporters has done much towards weakening the public confidence in the locomotive system. By these persons it has been argued, in favour of the comparative safety of locomotive transit, that the number of accidents bears no proportion to the number of passengers, which, in 1842 alone, were estimated at 18,000,000. But what force can there be in such a comparison? The question is not one of per centage or statistics, but, is locomotive travelling based upon correct principles

for general safety; for, were even the chances of death as only 1 to 1000, why should one be exposed to this contingency, or run this risk, if it can be avoided?

The total number of personal railway casualties reported to the Board of Trade for the quarter ending the 1st of April, 1845, was 39; being 22 deaths, and 17 injured. In the succeeding quarters of 1845, the numbers are probably greater.

It has, indeed, been attempted, from the official reports of preceding years, to show a progressive diminution of accidents from the 12th of August, 1840 (the date of the passing of the act for the regulation of railways) to the 1st of January, 1842; but there is no truth in the statement. During the last five months of 1840, by these official reports, the number of accidents of a public nature were 28, by which there were 22 deaths, and 121 cases of personal injury. In 1841, the accidents were 29, from which there were 22 deaths, and 71 injured. It is quite certain that though railway accidents vary in particular years, yet there is, in reality, no more diminution of them on any fixed data of calculation, than there was before that act was passed, or even from the opening of the Liverpool and Manchester Rail-

way. It is, therefore, quite a mistake, and has the tendency of misleading the public to suppose it otherwise. The remedy for the evil is much more likely to be found, and a cure effected, by open investigation than by attempting to conceal it or gloss it over.

As the railway movement must now proceed, it therefore becomes, as has been observed, of the greatest importance, both to the numerous undertakings established, or to be established, and to the convenience of the public, that every thing should be done, which care and attention can do, to make railway communication as perfect as possible. In order to effect this, much more is necessary than well-laid roads and well-constructed locomotive engines. Punctuality is of vast importance in railway business. Men who are to direct and manage should be men of ability and energy, capable of seeing quickly what ought to be done, and of enforcing discipline. It has been complained of — that, with the increase of railway business, confusion has increased, and uncertainty as to the arrival and departure of trains, which did not previously exist. It has been complained of—that, instead of growing more perfect by practice, the increase of business has made railway travelling somewhat less perfect,

less to be depended on, than it was. The movements of a great railway require to be governed with as much precision as a great army. Strict discipline should be enforced every where.

It is much to be feared, as the railway system is extended, that without the exercise of such vigilance as here enforced, confusion may be increased, and, instead of railway accidents being diminished by experience, they may be multiplied. It may be useful, therefore, to attempt to trace the real causes of the frequent accidents on railways.

RAILWAY ACCIDENTS.

Railway accidents, with the locomotive system, may be classified under two heads: —

1. Those accidents arising from mismanagement, or from railway administration, and from negligence.

2. Those arising from errors in railway construction or defect in any part of the working apparatus.

Under either of these heads, but especially the first, accidents are so numerous and multifarious, that it would fill volumes to describe them; and, indeed, it almost becomes a rare circumstance to

take up a newspaper without the eye falling on the words "Fatal or Serious Railway Accident."

Under the head of accidents attributable to mismanagement, or to the railway administration, and from negligence may be classed the numerous collisions of trains — the running of one train into another; the running of carriages off the rails from extreme or reckless driving.

Under the head of accidents, arising from defect in railway formations, may be classed carriages running off the rails from the imperfect state of the rails or sleepers; want of consolidation or solidity of embankments; improper curves; defective fences, bridges, viaducts, and tunnels; imperfect state of the engines; boiler explosions; ignition and burning of goods and carriages, &c. But some of these may also in part be attributed to mismanagement or the administration.

There is a third class of very serious accidents on railways, by which many deaths have occurred, but which it does not fall under the object of this work to dwell upon, although, no doubt, many of them might be averted were there existing a more perfect system of railway surveillance — I mean accidents which are commonly considered attributable to the imprudence of parties themselves.

I. ACCIDENTS ARISING FROM MISMANAGEMENT OF THE RAILWAY ADMINISTRATION, AND FROM NEGLIGENCE.

There is no class of accidents which it may be presumed admits of a more certain remedy than those arising from mismanagement. This mismanagement often proceeds from false economy in the employment of persons at a low salary who may be unacquainted with railways, and who cannot from previous habits appreciate the advantages of a well-maintained system of discipline,—or it may sometimes arise from retaining and using imperfect engines and from the want of a proper supply of these to work the line.

The want of an efficient head or strict superintendence at head-quarters extends its baneful influence over subordinates, and the railway system never can be efficient unless throughout every branch of it the most perfect vigilance, regularity, and attention be maintained — and persons be appointed, not because they have interest to obtain a situation, but because their services are valuable for the post they are to fill, from their knowledge and experience. By liber-

ality and encouragement, and the employment of able persons, accidents would soon be diminished. Without entering into minute particulars, I shall, for the sake of illustration, give notices of a few accidents under the first head, that of mismanagement, gleaned from the journals of the day.

ACCIDENTS FROM COLLISION.

A case was brought before William Jeffcock, Esq., the sitting magistrate at the town-hall, Sheffield, Aug. 15. 1845, which shows in a remarkable degree the sad results—probably death or injury to some fifty or sixty persons—which might have arisen from the gross misconduct of an engine-driver, in the employ of the Midland Railway Company, and which was only prevented by the extraordinary presence of mind of another engine-driver named Tallent.

Robert Bell, a man about 40 years of age, was brought up in custody, charged under the Railways' Regulation Act (commonly called Lord Seymour's Act), with gross misconduct whilst in the service of the Midland Railway Company as an engine-driver. For some time past, workmen have been employed on about two miles of one line of rails, in taking up the old and laying down new ones of a heavier description, and in consequence only one line of rails was available for the passage of the trains both ways. As a necessary precaution against any collision, men had been placed at signal-posts a short distance from each other along the portion of the line under repair, and the engine-drivers

had received strict and special injunctions never to pass over the 'points' at each end, at a greater speed than five miles an hour, and that upon a train being due from Masborough or Rotherham, the trains from Sheffield should stop upon the usual signal being given at the end of the piece under repair nearest Sheffield, until the train approaching in the opposite direction should have passed over the 'points' to its own line again. On Sunday afternoon the engine, of which the prisoner was the driver, was attached to the train which left Sheffield a few minutes before five o'clock, to meet the train from London at Masborough, and nothing unusual was observed in the prisoner's conduct until the train was stopped at a distance from any station, without any signal being given, and in the middle of the long cutting at Brightside. Upon the guard getting off his seat, and making inquiries, the prisoner was unable to say from what cause he had stopped the train, and the guard then saw from his appearance that he was intoxicated. After cautioning him, the guard allowed him to go on in charge of the train, and on nearing the point where the line was used both ways, he saw that the signal to stop was shown, and that the train due from Rotherham was approaching in the contrary direction, but on the same line of rails. Seeing that the prisoner did not appear to notice these, he called out to him as loud as possible to shut off his steam, and at the same time the stoker, who was on the tender, pointed out to the prisoner the danger they were in.

The prisoner then went to the side of the engine, but instead of shutting off the steam, he turned it the reverse way, thus putting the engine to its full power. They were then within a short distance of the points, and the driver of the other engine, seeing from the speed at which the prisoner's engine was coming, that it was impossible for him to stop before he crossed the points, and that a collision was

inevitable unless he could get over the points to his own line before the prisoner's train reached them, instantly put on the whole of his steam, and providentially got over just as the prisoner's engine passed within a few inches of the last carriage in his train. The two trains were proceeding at the rate of thirty miles an hour, over an embankment, and another instant would have brought them in collision with each other; and if this had taken place, it was impossible to say, and horrible to think of, what might have been the dreadful consequence.

A fearful collision took place on the Birmingham and Gloucester railway, on Saturday, Aug. 30th, 1845, by which one engine man was killed on the spot, another so much injured that his recovery is impossible; and the two stokers and several passengers have received severe injuries. On reaching the spot where the catastrophe had occurred, near the Defford station, the scene of wreck and destruction baffled all description. Two trains had evidently come into collision; the engines, shattered and broken, were lifted high in the air on a mass of broken carriages, trunks, and luggage, the *debris* of which was scattered over the road for a considerable distance; but, to add to the horrors of the scene, the burning cinders from the engines had set the wreck on fire, which a number of workmen were endeavouring to extinguish. Although several of the officers of the line were standing around it was impossible to ascertain with any certainty how the collision really occurred; one policeman, who appeared inclined to be communicative, being instantly checked by one of his superiors in authority. This much, however, was admitted, that one of the engine-drivers lay dead in a shed near the spot, that another had been conveyed to Worcester in a shockingly mutilated condition, and that two stokers and several passengers were more or less injured. The

damage done to the engine and carriages was roughly estimated at from three to five thousand pounds.

The collision appears to have taken place under the following circumstances: — the third class train leaving Birmingham at half-past four o'clock last evening, was due at Defford station at fifty minutes past nine. It had arrived safely near that spot, and was proceeding at its usual pace, when it had to pass a spot where, owing to some repairs, a single line of rails only was in use; while traversing these it was met by a special passenger train, proceeding on the same line of rails at a rapid pace towards Birmingham. Neither party being aware of the proximity of the other, a collision was the result, which has thus been attended with such serious and fatal consequences.

It would be premature, with our present limited means of information, to inquire by what means the two trains could thus come in collision; but that there was great blame and mismanagement somewhere is but too evident; and occurring, as it did, in the darkness of night, and when both trains were going at their full speed, it is only to be wondered at that a greater sacrifice of life and property had not been the result. It is but justice to the managers of this line to state that, although several fatal accidents to the company's own servants have occurred, yet that since the opening of the line, now nearly seven years, not a single passenger has lost his life or sustained any serious injury.

A frightful, but fortunately not a fatal accident, happened at Preston on Sunday, Sept. 18. 1845, at eight o'clock. As a train of nearly thirty carriages was starting slowly from the Preston and Wyre Railway station there for Fleetwood, and was crossing the Lancaster line, which is close to it, and before it had got half over, a train from Lancaster dashed right into it. The engine threw up and damaged two of the Fleetwood carriages, containing nearly one hundred persons, got off the rail, and was almost immediately

brought to a stand-still thereby, and by the weight of the two carriages, which hung across it like a pair of panniers. The carriages are such as are used for goods and cattle, but were this morning crammed full with human beings. The consternation was great enough, but providentially the injuries to the passengers are not serious. The cause of the accident may be attributed to the Lancaster train leaving Lancaster much past its time, and coming almost into Preston at nearly thirty miles an hour instead of seven or eight. Signals were made for it to stop, but the efforts of the driver were ineffectual to check the engine, which was a light four-wheeled one.

A railway train collision took place on the Newcastle and Darlington Railway between Sunderland and Brockley Whins, Oct. 1845. The following particulars are by a gentleman who was present:

We started from Sunderland by the half-past three o'clock P.M. mail train. Before we had proceeded above half a mile, we came in contact with the three o'clock train from Newcastle, both proceeding at a quick pace at the time. The collision was most fearful, and the consequences very serious to the passengers. Our passengers included several gentlemen, and about half a dozen ladies. Not a single person travelling with our train escaped injury. A Mr. Richardson and a Mr. Gutch were both badly bruised, and especially the latter gentleman, whose face was painfully disfigured. He was rendered very feeble owing to loss of blood. Our stoker had, I believe, his arm broken, while the engine-driver, seeing his danger, saved himself by leaping off the engine. A boy, about fourteen years of age, had his eyes frightfully bruised and cut. One gentleman sustained a contusion on the leg. All the women were severely stunned, but more particularly two of them, one of whom had an infant at the breast in her arms at the time. The child did not seem to be much the worse. Having

only one carriage with our train, it is miraculous that every life was not sacrificed. The massive iron of our engine and tender was shattered to pieces, and our escape from certain death can only be ascribed to a strong truck which was placed between our carriage and the engine. That coming from Newcastle was a larger train. Its engine was likewise much broken, and many of the passengers injured, but less seriously than those of the other train. What is inexcusable in connection with the sad occurrence is, that it took place at a junction of two lines (the one being a diversion for the conveyance of coals), where there is only a single row of rails, and where the signal flags for the Newcastle train to stop were actually hoisted at the time. When the engine-driver of that train, however, was asked why he did not stop, his only reply was, that he was aware he ought to have stopped, and did not know why he did not do so.

ACCIDENTS FROM ONE TRAIN RUNNING INTO ANOTHER FROM OVERTAKING IT, OR THE LIKE.

But railway collisions seem to arise more frequently from trains being run into from behind than from frontal concussion. Public attention has recently been called to the very dangerous practice of having an assistant engine to follow the trains from the serious accidents which occurred on the Eastern Counties' and other railways.

An accident having occurred on the Eastern Counties' Railway, on Monday, 29th July, 1845, one of the passen-

gers stated, that having heard a noise behind, between Romford and Brentford, he looked and saw an engine following the train at full speed: a violent shock took place, and a lady had her mouth much cut and her back injured.

The practice of having an attendant engine to push a heavy train up an incline is a common one. But this plan should, if possible, be avoided by the engineering arrangements, for where the attendant engine is permanently required to work the line, it remains as a permanent defect to the railway. Nothing can be conceived more positively dangerous in locomotive traction than placing passengers between two powerful machines, each itself sufficient to crush to atoms the intermediate carriages, while the least derangement of the motion of one engine, or the other, must be attended with a severe shock. Truly the passengers in such a position may say to turn from Scylla is to fly to Charybdis. If passengers knew the real danger of such a position, they would not be so eager to get into a railway train, but rather refuse at once, as a body, to enter the trains until the following after engine was removed. If a few of the directors or office-bearers of railways, where such a system is adopted, were accidentally subjected to the dreadful crush of a powerful assistant locomotive engine

rushing into their carriages, it might tend to discard for ever a practice so derogative to railway engineering. It is a practice indicative of trifling with the public safety, from mistaken economy, to save, perhaps, the expense of the formation of proper working gradients.

It was stated, in the session of parliament, 1845, by one member, that he had been much alarmed on the Dover line by seeing an engine propelling a train behind in which he was. Numerous letters in the newspapers frequently describe the alarm of passengers from the continuance of this practice. It was only lately much alarm was created to the passengers on one railway from two large trains, proceeding at the rate of thirty miles an hour, each propelled by a locomotive behind. There can be little doubt frequent concussions arise from the attendant engines, which, if unproductive of serious accidents, are never known to the public; and when to use an assistant engine behind the train is so obviously attended with danger, the wonder must be how any railway company can permit it. Where an excessive incline exists, injurious to the general working of the line, and which cannot be surmounted with one powerful locomotive, the assistant engine should be placed in front

of the train. On one railway, where a very steep ascent of 1 foot in 40 is regularly gone up by locomotives, the ordinary engine is first attached to the train, and in front of it a powerful auxiliary locomotive, made expressly to be used on the incline. When the summit is reached, the leading engine draws off the line and permits the second engine to proceed with the train without interruption. I have seen eighteen heavy-loaded carriages with passengers, besides luggage-vans, and the two engines ascend this incline at considerable velocity.

An accident occurred on Sunday, 17th August, 1845, at the Derby station, on the North Midland Railway, to the mail train from Leeds, which, though fortunately not attended with fatal results, was productive of serious injury and alarm to the passengers. The train had reached the ticket platform in safety, when the highly reprehensible practice of detaching the engine from the front, and placing it at the back of the train, to propel it into the station, was adopted. The engine not having been stopped in time, or the break not applied, the train was forced into the station-house with great violence, smashing the first carriage, and throwing it up on the platform, and breaking the strong iron and wooden balustrades that are placed there to keep off the passengers. All the passengers were thrown from their seats by the violence of the shock. Fortunately no bones were broken; but many persons received severe cuts and contusions, heads and faces were dreadfully disfigured, and one lady was sadly shaken by the concussion. Several minutes elapsed before any at-

tention was paid to the injured individuals, who were at length taken to the infirmary, where their wounds and bruises were dressed, after which they were enabled to proceed by the next train. In this accident not the slightest palliative presents itself for the recklessness of the railway people.

A dreadful collision took place upon the Eastern Counties Railway, in August, 1845, by which one person nearly lost her life, and several others were most seriously injured. The train, which leaves the station, Shoreditch, at half-past twelve, P. M., was proceeding at a rapid rate, between Romford and Brentwood, and when about half-way between those stations, a dreadful collision took place, by which the passengers were thrown violently from their seats, and dashed against each other and the sides of the carriages, occasioning considerable injury and alarm. It was some time before the train could be stopped, or the extent of the injuries ascertained. On the stopping of the train, it was found that the cause of the accident was the breaking away of the last carriage. The trains, at this portion of the line are propelled by two engines, the one before and the other behind; and, from some cause or other, the hindmost engine broke away the last carriage from the train and afterwards ran into it, by which the injuries were caused.

A very alarming accident occurred at the railway terminus at Bristol, on the night of Thursday the 18th September, 1845. A train from Gloucester ran into the Exeter luggage-train, while the latter was passing from the Bristol and Exeter to the London line, and seven trucks were smashed. There were two hundred passengers, but no one appears to have been injured. "Our informant," says the Somerset County Gazette, "attributes the damage to the carelessness of the engine-driver upon the Gloucester line as the Exeter train had the red lights burning on the last carriage."

A serious railway accident occurred on the Eastern Counties' railway, at the Waltham station, on Monday morning, November 10. 1845. A truck of the goods' train became disabled: this caused a stoppage, and before it was finally cleared the fish train from Yarmouth, to which a second class carriage and a truck, with sheep merely, were attached, arrived, and was detained close to the station. The mail train, due at 5 o'clock, being now expected, a person with an alarm signal was sent down the line for two hundred yards; but, from some unexplained cause, the train was not stopped sufficiently in time to prevent it running with terrific force into the first train. The effect was the destruction of the truck containing sheep, and the overturning of the second class carriage into a ditch. There were only two passengers in the carriage, one of whom had his right arm put out of joint, and was otherwise much bruised. The other was severely cut about the head. The engine of the mail train was completely overturned; the driver and stoker miraculously escaped without a bruise, and neither passengers nor carriages were the least injured.

On Wednesday night November 26th, 1845, an accident occurred on the Great Western railway, which providentially took place without injury to servants or passengers. There is an engine employed at the Box station to assist or push the luggage trains through the tunnel; and, in consequence of the darkness of the night, and the noise of the wind, the driver started this engine a little too soon, and, almost immediately, ran into the train sideways, striking one of the trucks near the end. The force was so great that the engine was thrown across the rails, and eight or nine trucks driven out of their course, with a third class passenger carriage with passengers. About a quarter of a mile on, the couples divided, and trucks, carriages, and all went into the bank, the rest of the train proceeding as if nothing had happened. The policemen on duty were immediately at hand, and de-

livered the passengers from their dark and dreadful state, but, strange to say, not one of them was injured. On proceeding to the engine the driver and stoker were alike uninjured, a heavy fall being all they had to complain of. Probably such a narrow escape was never before known, when it is considered that there were three engines in front and upwards of forty trucks; that the assistant or 'bank engine,' as it is called, struck the train within a few feet only of the passenger carriage, and that after the collision had taken place, and the following trucks were driven off the rails, they were dragged off a quarter of a mile, tearing up the cross wooden bars and the ground in their course.

On Tuesday morning, 2d December, 1845, about one o'clock, an accident occurred on the York and North Midland railway, in consequence of a special train running into a luggage train, a little beyond the Barnsley station. No lives were lost in the collision, though one of the passengers in the special train received a severe contusion on the leg and the stoker had his foot seriously bruised. Several of the carriages of the luggage train were shattered, and some sheep which they contained killed.

On December 10th, 1845, a collision took place, on the York and Scarborough railway, by which several persons were severely injured, owing to the reckless conduct of an engine-driver. He was the driver of a ballast-train; and, instead of propelling his train into a siding, previous to the expected arrival of a passenger-train, he continued on the main line till it was too late to prevent an accident.

On the morning of January 13. 1846, a somewhat alarming collision took place on the Cleland Railway, close to its junction with the Wishaw and Coltness line, at the Holytown Station. The wooden waggon which leaves the Newarthill depot at nine o'clock, with passengers for the Wishaw and Coltness train to Glasgow, was proceeding rapidly in this manner towards its destination, when,

whether from neglect on the part of the conductor, or the insufficiency of the drag, we know not, it came into violent contact with some stationary trucks at the Holytown Station; and the passengers' waggon being unprovided with buffers, springs, or anything that could soften the effect of such a collision, the whole of the passengers were projected roughly forward; many of them were more or less injured, and one gentleman, in particular, had one or more of his ribs broken.

On the Dover or South Eastern line, on 29th July, 1845, an accident occurred which, although not exactly originating from the use of the attendant engine behind, yet fully proves the danger which arises from engines following after a train.

It appears that when the evening train from Dover had arrived at Tunbridge, the last of the carriages, at the back of which the signal lamps showing behind were placed, was detached from the train. The train from want of management or circumspection (attributed to the confusion of the moment) was allowed to proceed without them. To complete the disaster a pilot-engine was absurdly sent after the train with the lamps left behind, and when the train was in the act of stopping at Penshurst station, the pilot-engine coming up suddenly, without perceiving it, ran into the train behind, when instantly three or four of the carriages were doubled up, and about thirty persons received contusions; one had his leg fractured, another received a severe injury of the spine.

The driver of the pilot-engine on his examination stated in extenuation, that in coming up with the train he did not observe it, till it was too late to prevent the concussion.

The person who sent forward the lamps said that he considered it his duty to do so, to guard against other consequences. The resident engineer observed that he could not say whether it was proper or improper to send forward the signal-lamps with a special engine. He admitted it was a new practice, but it was done for the best, to prevent perhaps a serious accident to the train when reaching without lamps the Brighton line at Reigate, where so many trains meet.

In this accident may be fully perceived the want of a calm and deliberate survey of the train before allowing it to start from the station, which it was the duty both of the guard and the station-keeper to have made; for if this had been done the accident could not have happened: it shows the folly of a hasty, blustering system of confusion and mismanagement, and the evil effects resulting from a reckless, constrained, forcing system of undue speed, not permitting a sufficiency of time at stations either for passengers to join or leave trains, far less to disengage or attach a carriage to the trains. It also proves the extreme danger in almost any circumstances of permitting one locomotive engine to follow the path of another. For without there can be a sympathy, which is an absurdity, between the engines to regulate their respective velocities, they may be brought in an instant in contact.

Few accidents can be traced more distinctly to clear and defined causes, and it is fortunate it is so; for could no explanation be given of it, a well-grounded alarm would exist against the whole railway locomotive system, which would tend to the entire loss of public confidence in this mode of transit.

Another serious one occurred on the 30th July, 1845, on the London and Birmingham Railway, evidently proceeding from want of management, and the defective arrangement and intersection of the rails already noticed; but which has been attributed to a dense fog preventing the red signal of danger being seen at the Camden Town station. The train which should arrive at the Euston Square station from Birmingham, about five o'clock in the morning, ran into the goods' train as it was crossing the line; two of the leading carriages of the train were thrown over by the concussion, and several of the passengers were seriously hurt. One gentleman had a dreadful fracture of the knee joint, and was otherwise injured, and died in the University College Hospital seven days after the amputation of the limb.

In this accident, which might have been still more dreadful in its consequences, it is stated, no fault was imputable to any one, that it was an unavoidable accident, arising from the impossibility of the engine-driver perceiving the signal, in consequence of the fog; although, at the same time, it is admitted that the trains had arrived before the regular time, and the goods' train was

fifty minutes behind its time. The signal-man, at the Camden Town Station, stated that, although he turned the red signal when the goods' trains began to move, still this signal was not sufficient in a dense fog. There was sufficient admittance of the confusion of the arrangements, and the necessity pointed out of having distinct and easily heard signals adapted for foggy weather. A blue light might be useful, burned when the goods' trains begin to move, and at the time the trains are due, and occasionally to indicate that the way is clear.

The verdict given by the jury was, "That Charles Dean died from an injury to his left leg, caused by an accidental collision on the London and Birmingham Railway near to Camden Town; and that the engine marked 91, belonging to the company of that railway, moved to the death of the deceased; that its value is £1000; and that they make a deodand of the same engine to the extent of £1000."

In delivering this verdict the jury express their opinion that the laws and regulations of the London and Birmingham Railway Company for the guidance of servants have been carried out very inefficiently for some time past; and farther, the jury consider that the area of the Camden Town station, and the system of rails there laid down, are too much cramped and limited, consistently with the public safety.

ACCIDENTS FROM EXCESSIVE SPEED.

Another class of accidents arises from mis-

management, but from very opposite causes than misarrangements, and which may be more properly attributed to foolhardiness, rashness, or imprudence, although others consider it displays fearless intrepidity. And perhaps accidents arising from this cause are the most numerous; the least imperfection in the working machinery makes their effects more serious. In general, the complaint with those who travel much on railways is, that they go too fast and not too slow. A few years ago twenty miles an hour, as has been previously shown, was considered fast travelling; while fifty or sixty, and even seventy miles, including stoppages, is now done; and an express train has gone with a load of eighty tons, exclusive of engine and tender, at the rate of sixty-five miles per hour, and the regular average speed on the Great Western is from 41 to 47 miles per hour. All this excites little wonder, and will hardly even satiate the growing propensity for rapid travelling.

Some entertain the idea that there is just as much personal risk in the event of the collision of two trains, when going at a moderate speed, suppose thirty miles, as there is at sixty miles an hour, and that therefore one may just as well go by the swift train as by the slow. It may, how-

ever, reasonably be inferred, that at the increased speed, if an accident does occur, it is likely to be more extensively destructive. The effect indeed of the collision of a body in rapid motion with one with lesser momentum is developed in the general destruction of the latter, as is fully proved in collisions, both in railway trains and steam-vessels; hence it is necessary to curb the undue speed of the one, if it was no more than to prevent the destruction of the other.

There cannot be any doubt that in proportion as the velocity or impulse is increased, the controlling power is diminished. If the speed is increased from thirty to sixty, or seventy, miles per hour in locomotive trains, this increased impetus must make the train less under control, or more difficult to be quickly stopped, even by reversing the engine, and therefore the violence of the concussion must be more dreadful in the event of an obstruction appearing on the line. There is an example of this afforded by a fatal accident which occurred on the Birmingham and Bristol line, in June, 1845.

The train was going at the maximum speed of sixty miles per hour, when an old woman was observed on the line, and although the steam was instantly blown off, and the engine reversed two hundred yards before coming to the place where the woman was, such was the mo-

mentum that the train, after passing over and carrying the fragments of the body forty yards, absolutely proceeded from 400 to 500 yards from the spot where the accident happened before it could be stopped.

Numerous examples might be given, to show that however well-managed a railway may be, with increase of speed the danger from accidents, to a certain extent, must be increased, for no precaution seems to be able to guard against obstructions occasionally accidentally arising, and which may even be mischievously made, and these must continue to form a certain amount of hazard in locomotive travelling.

A striking accident lately occurred, showing the violent effects of concussion from speed, but also combined with imperfection of the rails.

On June 16th, 1845, the luggage van of an express train, with a great number of passengers, on the Great Western Railway, which is stated to have been propelled, at the moment of the accident, at the rate of nearly seventy miles an hour, ran off the rail without any assignable cause, although there can be no other probable than a deficiency in some part of the rails. It ran for half a mile unperceived on the longitudinal timbers without displacing the carriages, till it came in contact with a girder at a bridge, when the wheel ran into the ballast: fortunately the engine and tender separated from the carriages, but so sudden and fearful was the catastrophe, that two first class and one second class carriages were thrown with fearful violence off the line and down an embankment, about fifteen feet in depth, with an

alarming crash. One of the carriages turned twice over and remained with its wheels in the air; one of the carriages was thrown completely across the line of rail; no lives were lost, but forty persons were more or less injured. A repetition of a similar accident happened near the same place on the Friday afterwards, when the rate of speed was forty-five miles an hour.

On these accidents, the inspector-general of railways, Major-General Pasley, reported that they arose from the elasticity of the timber and rails originally laid down, and the rails being too light; that the remedy was, first, to replace all the light sleepers and hog trough rails with the stronger and heavier sleepers and rails of Mr. Brunel's last approved pattern; secondly, that experience has proved the impropriety of mixing light four-wheeled and heavy six-wheeled carriages on the same swift train, and that the former should be discontinued; and thirdly, to have a carriage without passengers next the tender, with six wheels, the same weight as the passenger carriages, which may be used for luggage, in order that a carriage in this position may receive the first shock in case of accident. A writer in the "Times" paper attributes this accident, with much probability, to the old rails being so reduced, being only 1¼ inch high, that the tire of the wheels of the carriages did not support the whole weight, but the flanches ran over the raised nuts, the tire in some places being clear of the rails, as the tops of the nuts were bright from the friction of the flanches. The official report, however, clearly admits that the defective construction of the rails was the cause of the accident; and this fact proves, not merely the necessity of precision in the construction of rails, but also of constant circumspection, as the best means of preventing railway companies being constantly assessed in damages.

An accident occurred on Wednesday, 24th Dec. 1845,

within a mile of Thetford, on the Norwich Railway, by which the engine-driver and stoker of an up train were killed. It appears that the engine, when going about 50 miles per hour, down an incline of 1 in 100, ran off the line, from the left to the right, upwards of 200 yards when it ran down an embankment and became embedded in the earth. In its progress, the chain which connected the tender with the carriages snapped, and to this circumstance chiefly the passengers were indebted for their safety, because the tender, having disconnected itself from the engine, fell right across the rails, and thus formed a barrier against the further progress of the carriages. If this fortunate circumstance had not taken place, the carriages must have been dragged in the wake of the engine, and precipitated along with it down the embankment. The stoker leaped out of the tender, and was killed by collision with the carriages. The driver was killed on the opposite side of the rail, close by the place where the engine lies embedded, and distant from the stoker about sixty yards. Some idea of the violence of the collision may be formed from the fact that the solid timber of the carriages was riven as if it had been exposed to the fire of a battery. The luggage waggons attached to the tender were smashed to atoms.

The investigation relative to the death of the engine-driver and stoker, killed by this accident, was resumed on Tuesday, January 13. 1846, and after the examination of General Pasley, twelve of the jury returned a verdict of "Accidental death, caused by the imprudent conduct of the engine-driver, in going at excessive speed."

This accident arose, evidently, from over-driving the engine, the driver trying to make up for lost time. General Pasley stated, in giving evidence, that he had frequently warned engine-

drivers of the danger they were incurring when driving at a rate verging on 50 miles an hour. It is a rule to shut off the steam on descending gradients, but in this instance it appears from the evidence that the engineer did not shut off the steam till after the engine had jumped off the rails. General Pasley also objected to the peculiar construction of the engine; but without entering on this point, it is remarked in the "Civil Engineer's Journal," February, 1846, "a much more serious source of error on the Norfolk Railway appears to be the manner in which the transverse sleepers are laid, being made of unsquared timber sawn in half lengths. Now these half cylinders are not (we understand) laid with their flat side downwards, when they are firmly supported by the soil, but, on the Norfolk Railway, the sleepers are laid with the flat side uppermost, and a pressure on one side of the sleeper would cause it to slip round."

A very serious accident occurred on the Great North of England line, on the 1st January, 1846. For some days engineers have been working experimental trains on the Great North of England line, and on that portion between Thirsk and Northallerton more particularly, to test the actual amount of speed that could be attained. This morning a new engine was brought out, drawing carriages weighted at 70 tons, and at half-past nine o'clock away

went the train like an arrow, reached Thirsk station in safety, when the speed was increased to the greatest momentum, and when about 400 yards beyond the station, a violent oscillating motion was observed, which increased every yard, until the engine was thrown upon her broadside against a slight cutting, upon which some of the carriages were thrown, and all more or less damaged. The shock had been fearful, and yet the engineers, most providentially, escaped injury; one man only, the poor fireman, was thrown on his head upon the opposite rails, and so seriously injured that he was not expected to survive very long.

A very serious collision took place at the Chesterfield station, on the Midland Railway, on Tuesday, January 13. 1846. The down train from Derby to Leeds arrived at the station with most terrific speed, and although her steam was shut off, in consequence of the rate she was going at, was unable to stop, and ran with fearful violence into a mineral train which was crossing at the moment. The engine of the passenger train was thrown off the line, and it was almost a miracle that none of the passengers were either killed or wounded.

Undoubtedly the danger from great increase of speed may be rendered less with judicious management; but as engines are increased in power, and increased momentum is given them, they are rendered liable to be easily carried off the lines by the wheels meeting the most trifling obstruction. It must be obvious the entire command over the machine becomes more difficult, and it therefore becomes a matter of deep consideration, what limit should be given to the

velocity of locomotive trains, or what should be maximum speed, as either prudent or safe; indeed it appears, perhaps, a step required to give security to the public, that some legislative regulation should be made on this subject. Few will not admit that risk must arise from the foolhardy manner those entrusted with locomotive engines are so often apt to view danger, arising, probably, from the same feeling which makes those who reside near to the crater of a volcano callous as to danger. Notwithstanding, therefore, every precaution, or the best rules for railway management which can be devised, there will still remain the liability to accidents from rashness and imprudence. As railways become extended over the country, and almost the only mode of conveyance, we may be prepared, at first, even with improvements on the system of locomotive travelling, from its extent, for, perhaps, an increase of accidents. These will be lessened, however, to a great degree on the aggregate amount by increased experience and good regulations. As the safety of railway travelling is wholly dependent on the degree of perfection in the management the science of locomotion has attained, it should therefore be an object to be guarded against, that great increase of speed, while it

obviously increases the risk, may not beget a system of over-confidence and fearless indifference which is often the precursor of some fatal result.

How many fearful accidents have we seen from causes which no one could anticipate, and which generally come when most unsuspected, and when least danger is apprehended.

ACCIDENTS FROM NEGLIGENCE.

That many of the preceding accidents owe their origin in a great measure to negligence, cannot be disputed; but there are, however, some accidents so distinctly attributable to carelessness that the cause of them cannot be mistaken.

An accident occurred, June 10. 1845, on the Greenock line near Paisley, which originated from negligence or want of circumspection. A special train was hired at Greenock, and the passengers came up with the superintendent of the Greenock station on the tender without any carriage attached; they came up with great speed, and, when close to the Paisley station, came unexpectedly on men who were repairing the line, and who had at the time a piece of the rail lifted. There was neither time for the workmen to give the signal for the engine to stop, nor could the driver arrest its progress, but as soon as he saw the danger they were in, the steam was turned off and the pace slackened

as far as possible, but on coming up the wheels ran into the uncovered earth, and were imbedded to the axle. The tender and engine were separated and thrown over by the collision, but fortunately no person was seriously injured. This almost miraculous preservation of life most probably arose from the men in the tender keeping their places, and taking a firm hold, at the time of the collision, to which course they were advised by the superintendent with much presence of mind.

Another accident occurred on Aug. 1. 1845, of a most serious and alarming nature, upon the Northern and Eastern or Cambridge line, which miraculously was not attended with most fatal consequences. It originated evidently from mismanagement, or culpable negligence. It appears that in the up-train, which started from Cambridge about eight o'clock, the passengers were alarmed by a sudden collision of the carriages at the new branch to Newport. It was found that the tender had got off the line by the neglect of the man to set the points. Fortunately the train had just been put in motion, and the impetus was not great, and so no casualties occurred.

A melancholy and fatal accident occurred on the North Midland Railway, at Masborough, in Oct. 1845, by which a poor man lost his life. One of the goods trains from Derby had arrived on a Saturday at the Masborough station, at half-past one o'clock P.M., when a portion of the carriages—six in number—laden with iron, were detached from the train in order that they might be run into one of the sidings. A fireman, named John Turner, was about to do this, when the deceased unfortunately attempted to cross the line, just as the train was shunting or backing. He was knocked down, and three carriages passed over his legs and thighs, when, strange to say, with his legs dissevered, he managed to drag himself off the rail before the three remaining carriages, with engine and tender,

passed over him. He was promptly conveyed to the Sheffield General Infirmary, where every attention was speedily paid him; but so great had been the shock to the system, accompanied with loss of blood, that he died at five o'clock the same afternoon. An inquest was held, when the jury returned a verdict of "Accidental death," accompanying the verdict with a request that the coroner would write to the secretary of the Midland Company, and say that it was the opinion of the jury that a man should be always stationed on the first carriage of the train when shunting.

Accidents from mistakes of the night signals are attended with very serious consequences: they generally arise from mismanagement or negligence, except perhaps in weather when they cannot be seen.

On Saturday, January 3. 1846, owing to mismanagement respecting the night signal, one of the Leeds luggage trains ran into a York luggage train; happily no one sustained bodily injury.

An accident occurred to the mail train proceeding north, on Friday evening, January 23. 1846, near the Sessay station, on the Great North of England Railway. The train was earlier than usual, and was going at the rate of 10 miles an hour past the station, when another train was discovered in advance on the same line, and though the steam was put off instantly and the break applied, a violent collision took place, which broke the engines, damaged several of the carriages, and injured a number of the passengers. One lady was much cut about the head and face, and one gentleman received a severe blow on the leg. It

appears that the train run into was a coal train on the wrong line, it being changing from one to the other when the mail train was observed coming, and as the coal train could not get out of the way in time, the engineman put on the steam and pushed it along in advance of the mail train, so as to afford the latter an opportunity of stopping as soon as the obstruction was discovered.

The engine-driver who had charge of the coal train was brought up a few days after, before the sitting magistrates at Darlington, charged with wilfully obstructing the line of rails, and not having proper signals placed to prevent accident, whereby the collision took place. He was found guilty, and adjudged to pay a fine of *5l.*, and in default of payment to be imprisoned and kept to hard labour in the House of Correction for one month. He paid the fine and was discharged, but has been dismissed the company's service.

How very simply a serious accident may arise on railways from the least want of strict attention and careful survey, I witnessed, not long since, when a night train on a railway started.

The carriage nearest the engine had not been properly placed on the turn-table, or the table might not have been locked; and when the engine started, it was drawn off the rails, and such was the noise the steam of the engine made, that the driver did not hear the repeated shouts to stop. In another moment, the whole carriages would have been overset and perhaps dashed to pieces in a tunnel which the train was entering, when, fortunately, the passengers were relieved from their perilous situation by the driver happening to look behind. The carriages were half over, and so jammed that the train could not proceed; and other

carriages had to be got to forward the passengers upon the other rails.

This occurrence was said to be a mere accident, which could not have been foreseen; but its origin is easily traced to want of circumspection, and probably to the turn-table not being set to the right position. The occurrence, however, strongly evinces one of the most prominent defects attending locomotive travelling,— namely, the insecurity arising from the helplessness of the passengers, the total want of the power of communication between them and those in charge of the train or with the engineer, and likewise the obvious defect arising from the want of a quick and easy mode of communication between the guard and the engineer, and between the guards, when there is one at the head and another in the rear of the train, although many of the trains have only one guard. In corroboration of this, it has been publicly stated, in reference to the accident mentioned on the Great Western line, that, had there been a proper look-out by a guard at the last carriage of the train, and had means existed of communicating with the driver so as to stop the train, the accident might have been prevented, as many of the passengers had observed something was wrong.

II. ACCIDENTS FROM RAILWAY CONSTRUCTION, OR FROM DEFECT OF ANY PART OF THE WORKING MACHINERY, AND FROM IMPERFECTION OF THE ENGINE.

Under this second head — Accidents arising from Railway Imperfections — a few examples may be given by way of elucidation.

All railway companies have a person to examine the engines when in the stations at both ends of the line, before starting, which is essential for the full performance of their duty, and to insure the safety of the passengers. The driver should be at the station some time before the time of starting, to examine and oil the engine; but until — as has been well remarked and fully shown at the coroner's inquest on the Midland Railway's accident — an educated class of engineers are prepared for the duty of driving, and are paid with a liberal salary, no proper check can exist against foolhardiness and carelessness. Some excellent regulations were drawn up for the first appointment of engine-men, and adopted by the Directors of the London and Croydon Railway in 1840;

but perhaps the best and safest check which can exist is, that, in every large town where one or more railway termini exist, an inspector should reside, who should be totally unconnected with the railway companies, and have full powers at all times to examine as to the condition of the engines, the mode of working, and state of the railway. This will be the more necessary from the numerous railways now making, many of which are unlikely to yield large return, and so will require some inducement for those in the management to expend money on them.

The following fatal accident fully realises the truth of the preceding observation; for, had the steam-engine been subjected to a proper scrutiny before being despatched, or had sufficient vigilance and prudence been exercised, the accident could not have happened.

The accident occurred on the evening of the 19th of May, 1845, on the Edinburgh and Glasgow line. A special train from Glasgow, starting an hour and a half before the regular one, was run into by the latter within a few miles of the Edinburgh terminus, and the unfortunate person, who had hired the special train, was crushed to death.

The cause assigned for the delay of the special train was, that the valve of the pump had gone wrong, and, from leakage, about an hour and a half was lost on the distance of 46 miles. If the inspector sent away the engine in a perfect state, how this could have happened requires ex-

planation. But surely, when the engineer of the special train found he was losing ground, he should have run no risk when the object for which the train was hired was at an end, for what purpose could there possibly be in proceeding when the regular train was close behind. He was warned of its approach, but in place of withdrawing from the line, although he came without lamps and left no word at the station to warn the next train that he had none, he went on, and at length, becoming conscious of danger, he came off the engine himself, unfortunately leaving the passenger in the carriage, and sent back the fireman along the line with a signal to stop the train, but this was unperceived by the engineer or guard of the approaching train, and hence the catastrophe. Now all this was said to be the result of a mere concatenation of circumstances which could not have been averted; but there is no doubt that the real cause of the accident originated in sending out an engine in a leaky and imperfect state; and could the driver establish this fact, the blame cannot be so much attached to him for the consequences which have arisen from conflicting circumstances, for the fault lay more with those who sent out the engine.

Since this was written, William Paton, the superintendent of the engine department of the company, and Richard M'Nab, the engine driver, have been brought to trial, 8th November, 1845, at the bar of the Criminal Court of Scotland for culpable homicide; and the verdict of a jury has been to find both parties guilty. The former, Paton, has been sentenced to a period of twelve months', and the latter, M'Nab, to nine months' imprisonment. Mr. Paton, in his defence, endeavoured to prove that the fault of the engine being in imperfect condition did not lie with him, as he had frequently warned the head manager, or board of management, both verbally and by a written report, that he had not a sufficiency of perfect engines to work the line, and

that the object seemed to be to get as much work as possible out of the old engines before laying them aside; and that, therefore, the blame could not be imputed to him, but to the system of management. Witnesses spoke in high terms of his general character and of his knowledge and ability. The judge, in his able address when passing sentence, drew the distinction between the culpability of the different parties; and showed that by mal-railway administration, directors made themselves personally responsible. Had the defence of Paton, therefore, made out that he had insisted, and been positively refused, a proper supply of engines to do the work of the line, the probability is, that other parties connected with this railway would have been held responsible.

An accident occurred on the North Midland Railway, at Masborough, Oct. 21. 1845. The engine of the passenger train having got out of order, a message was sent back at 2 A.M., for another engine, which, coming up at a rapid rate, and not slackening pace in time, ran with immense force into the train. The last carriage was forced from off the rails, and the buffers were forced through into the next compartment of a first class carriage. One gentleman had his leg broken above the knee, and another had a compound fracture of the left leg, and both died. The real cause of this accident distinctly owes its origin to the imperfect state of the engines.

The coroner's inquest on police-sergeant Stubbs, which was adjourned in order to have the evidence of Walker, the stoker of the pilot-engine, was resumed on Monday, Dec. 8. at three o'clock, in the council chamber of the Court House, Leeds. Walker was in attendance at the time required, having been brought from Brighton, where he had been residing since his discharge from the service of the Midland company. His evidence of the progress of the pilot-engine up to the place where the collision took place cor-

responded, in every material particular, with his deposition at the inquest on Mr. Boteler. On that occasion he stated, that, as they were coming up to the mail train, a white light was seen, and continued to be exhibited, up to the time of the accident taking place. It was afterwards suggested that this might have been a green light, which, at a distance, has the appearance of a white one; and Walker had gathered his impressions respecting it when at a considerable distance from the mail train. Upon the question he was strictly examined, at the adjourned inquest, on Monday, the 1st December, 1845, by Mr. Blackburn, the coroner, and he made a very confused statement as to the use of signals. It was evident that he was, in a great measure, ignorant of the rules laid down by the Midland company for the use of signals; and he could scarcely be expected to be otherwise, for he said he was a very bad reader, and the rules had never been read over to him. He was clearly deficient in a very important part of his duty, and grossly incompetent to be confided with any portion of the management of a railway locomotive engine. He asserted that the red lights were seen by him and Wheatley half a mile distant from the train before them; and, from that time, they did everything they could to stop their engine; although he afterwards admitted that an engine, going at their speed, could be stopped in three hundred yards. This statement being in itself a decided contradiction of his testimony, in other respects so very equivocal, the coroner said he thought himself scarcely justified in continuing his examination. Eventually the jury decided to dismiss from their minds this man's evidence. The coroner then made some suitable observations upon the evidence, after which the jury consulted together, and returned a verdict of manslaughter against the driver, Thomas Wheatley.

Equally dreadful results arise from defects of

the locomotive boiler, or its mismanagement, some examples of which have been previously given.

On August 21. 1845. — On the Great Western Railway, shortly after the arrival of the train, which left Reading at half past seven o'clock, at the Maidenhead station, one of the tubes of the boiler exploded, rendering it impossible for the engine to proceed onwards to Paddington. An express was immediately sent to Mr. Howell, at Slough, who lost no time in hastening to Maidenhead with another engine; but, unfortunately, just as this engine was starting with the delayed train and passengers towards town, an accident occurred, rendering the engine from Slough useless; and it was not until the Oxford train arrived at Maidenhead, upwards of an hour and a half afterwards, that the passengers were enabled to proceed on their journey. Just as the day mail train to Exeter, which leaves Paddington at a quarter-past ten, was on the eve of starting the same morning, from the Paddington terminus, a similar accident to the foregoing occurred to its engine, one of the tubes of the boiler suddenly bursting, and thus completely disabling the engine attached to the mail train, and delaying its arrival at Slough, the first station she stopped at, nearly an hour. This train, and the one which left Paddington an hour afterwards, both arrived at Slough at the same time. Notwithstanding the bursting of the tubes, no injuries, in any one case, were sustained by the engine drivers or stokers, nor indeed by any persons connected with the company.

In August, 1845, as the half-past eight parliamentary train, or that which carries passengers at a penny per mile, was standing at the Walton station on the South-Western Railway on its down journey, the engine being then taking in water, and the engine-man beneath examining his engine, as is customary during a stoppage, a sudden explosion took

place, and the steam rushed out at the fire-door in a direction so that the engine-man was severely scalded. The fireman escaped unhurt. The only other person who sustained injury was not a passenger, but a by-stander. He was struck on the back of his head by a piece of coke, but with no great force.

A dreadful and fatal accident occurred October 17. 1845, on the Great Western line, to the train which left Paddington at 8 A.M. At West Drayton, about half past eight o'clock, an unusual quantity of steam was put on from the train having been behind its usual time. The engineer was about to decrease the power of the steam when the funnel of the boiler exploded, the fragments of which flew in all directions, with one amazing and fearful discharge of steam. The unfortunate man was thrown from the engine and expired before he could be carried to West Drayton. The passengers escaped uninjured.

ACCIDENTS FROM IMPERFECTIONS OF THE RAILS AND RAILWAY CURVES.

Another class of accidents under preceding head originates not so much from mismanagement, as from imperfections in the construction of the rails, accompanied by negligence, and these are often productive of the most serious consequences.

One class of these accidents arises from carriages running off the rails. A few of these may be noticed: —

An accident occurred on the 2d June, 1845, to the train which left Gateshead at five o'clock for Sunderland, when four miles from Gateshead, the engine became detached from the carriages, and some of the latter were precipitated over a considerable embankment.

The recently opened portion of the Northern and Eastern Railway, on which an appalling accident took place, on the 4th August, 1845, was the scene of another frightful occurrence on Tuesday afternoon, August 19th, 1845, of a somewhat similar character to the one that occurred on the line on the 4th instant; and although it was not attended with such a deplorable loss of life as the previous one, yet several of the passengers received serious contusions, and the escape of human life may be truly considered miraculous. The train that left London at half-past eleven, on arriving about two miles beyond Waterbeach, seven miles from Cambridge, and the same distance this side of Ely, the engine ran off the rail on the left side, dragging the tender and the whole of the carriages after it. Fortunately this part of the line is a perfect level; and the engine had not travelled more than thirty or forty yards over the ballast, before it completely turned over with the tender into a drain partly full of water. The luggage van, by the sudden jerk, became detached, and the wheels were perfectly imbedded, and thus brought the remainder of the train to a stand-still. The head guard, who was in his usual seat on the top of one of the carriages, perceiving that the engine had run off the line, jumped from his place on to the road. The step of his seat was driven through the plate-glass window of a first class carriage, in which were seated three ladies, one of whom was much cut by the glass. During the confusion, a painful alarm was created for the safety of the engine-driver and stoker, as they were seen to be on the engine when it capsized. To the surprise and gratification of all, however, the poor fellows, evidently much terrified,

were seen wading through the water in the ditch unhurt. It appears, that as the engine turned over, they were thrown some distance from it into the pool, and were accordingly preserved. On the guard making a strict examination as to what was likely to have caused the accident, they found about three inches of metal cut off one of the outer rails at a joint, and on searching about found the piece, which they took charge of, and brought it up to town yesterday, and delivered it into the hands of the superintendant of the line, in order to assist the official inquiry which will be instituted relative to the occurrence.

A succession of accidents occurred on the Eastern Counties Railway, on the portion opened between Bishop's Stortford and Ely, which produced much alarm; for in addition to the frightful accidents at Littlesbury and Waterbeach on Tuesday afternoon, August 19, 1845, there have been four others within a few days following each other arising from the engine running off the rails; two of them between Waltham and Broxbourne, another a short distance from Bishop's Stortford, and the fourth, which was somewhat alarming, between Cambridge and Ely. In the latter case, an engine was sent down to Ely, fortunately without any carriages, and, according to the driver's statement, he suddenly felt an excessive jerking which convinced him the engine had got off the lines, and was running on the sleepers. He shut off the steam, and jumped on the side of the rails. The engine, which was one of the largest description recently introduced on the line, dashed on, and went down an embankment of considerable depth, and buried itself in a meadow beneath. The funnel was carried away, and the engine injured. The cause of the running off was found to be that the wheel had gone off at a joint of the rails; but whether that had arisen from any neglect on the part of the plate layers, or by one of the wedges of the chairs getting loose, whereby the rail got free, could not be traced. The

piece of metal that was cut off the rail, at the joint where the engine ran off, was picked up by the guard and was kept for inquiry.

Several railway accidents from trains having been thrown off the rails can clearly be traced to the short radii of curves, the evil effects of which have been previously described. On many railways double curves of short radii are numerous; and from the elevation which must be given to the outer rail at these, the least sinking of the sleepers, which frequently happens in newly opened lines, may be attended with disastrous consequences. The sleepers retaining their position merely by the weight of the ballast, want of consolidation is fatal to their stability. With such facts constantly before the public, and with accidents of so frequent occurrence, it should be incumbent on railway companies to avoid the least appearance of a niggardly system of engineering; the more especially as most companies possess a monopoly of a road. Besides which cheap schemes of railway construction proceed on mistaken views; — such plans must prove generally dearest in the end, from the constant repairs and alterations that are rendered necessary.

The accident often arises from a combination of causes, as a curve at the foot of an incline

taken at an improper speed, and not slowing the engine in time. The following fatal accident arose from this cause: —

A very serious and alarming accident occurred on the Northern and Eastern Railway with the down train, 4th August, 1845, which, miraculously, was not attended with more fatal consequences. It appears that the train going down an incline of 1 in 158, with a curve at the bottom of it, was suddenly thrown off the rails in taking the curve.

The passengers were alarmed by a shock, accompanied by an explosion. The engine, after breaking away from the tender, had crossed the rails and was lying bottom upwards on the side of the cutting. The tender was at some distance in advance of the train, doubled up, while a van was on fire; two carriages next the tender were much broken. When the passengers were extricated it was found, providentially, that few were much hurt; but the guard had one of his legs fractured and much crushed, and died at Addiscome Hospital, while the unfortunate stoker was found under the fire-box of the engine, crushed to death, and almost burnt to a cinder. This calamity produced the greatest consternation. Several hours elapsed in replacing the rails, both lines nearly to the extent of 200 yards being torn up and the rails twisted in all forms. The unfortunate guard had his leg amputated, and died soon after. At the coroner's inquest, held at Cambridge, the greatest discrepancy of opinion arose as to the real cause of the accident: the people belonging to the company stated that the train was not going faster than usual, and that the accident originated from a flaw in one of the rails. One can scarcely conceive how such an idea could be entertained, no flaw in the metal such as described could throw the engine and tender off the rails with the violence described. One of the wit-

nesses, Cox, in his evidence, distinctly deposed to the leaping motion of the carriage on the rails before the carriage ran off the lines. There is little doubt that the accident arose from undue speed in going down the descent, having a curve at the foot of the incline.

The opinion of General Pasley on this accident seemed to be, that it was produced from the rapidity of speed down the incline and the yielding of the rail at the curve from want of sufficient consolidation. He stated that the engine was sent many yards from where it first deviated from the line, showing the great impetus it was under at the instant it occurred, while the flaw found on the rails may easily be accounted for from the lurching of the engine in its velocity.

The coroner at this inquest remarked, "that almost every accident he had been called on to attend at railways had arisen from curves." This is an opinion deserving the serious consideration of engineers and railway proprietors.

ACCIDENTS FROM IMPERFECT FENCES.

An accident occurred on the Ayr line, on the 21st of May, 1845, when the train ran over a bullock in spite of every effort to stop the engine.

Another accident of a similar kind occurred on the 15th of June, 1845, on the Eastern Counties line. A horse, which had strayed on the line, was cut to pieces, and some of the carriages were thereby thrown off the rails, but, by the skill of the engineer, the train was stopped and the passengers escaped.

Owing to a cow having negligently been allowed to stray on to the Sheffield and Manchester line, by a drover from Penistone market, after dark on Monday night,

October 13. 1845, an accident occurred, which had well-nigh been the destruction of a whole train of passengers. Shortly after the train had left Dunford Bridge, and while it was dark, a shock was received which threw both engine and train off the line, seriously injuring several of the carriages, and almost crushing the guard to death. As soon as the passengers could be got out of the carriages, it was ascertained that a cow had got upon the line, and the engine had come in violent contact with it. The poor animal was nearly cut in two, and, of course, killed on the spot. Information was immediately sent to the Sheffield station, and a pilot engine promptly despatched at ten o'clock at night.

A train going west on Saturday evening last, Nov. 29. 1845, after dark, on the Newcastle and Carlisle railway, encountered some thing lying across the rails between Haydon Bridge and Haltwhistle, which turned out to be a cow, which was instantly killed. It seems the animal had jumped out of a truck from a train going east, and had broken its thigh. The engine, the Rapid, was thrown across the rails, and the driver into the hedge, but he escaped unhurt, and no damage was done otherwise.

ACCIDENTS FROM IMPERFECT EARTH WORKS AND BRIDGES.

An accident of a very frightful character occurred on Friday evening, December 5. 1845, on the works of the Shrewsbury, Oswestry, and Chester Junction Railway, between Gresford and Wrexham. The workmen and stonemasons employed on the works at Gresford, it appears, were in the practice, on leaving their work in the evening, of getting into the earth waggons, and being propelled up the

line to Wrexham. On the evening in question about forty of them had taken their seats in the trucks, and were proceeding at a rapid rate when, on arriving opposite the race-course, near Wrexham, the fireman's waggon got off the line, and ran down the embankment, dragging with it the remainder. One man was found among the lower trucks, frightfully mutilated and quite dead. Another labourer was discovered with his left leg severed completely. A third poor creature had his left leg broken in three places, while seven or eight others were more or less injured. An inquest was held on the body, which occupied a considerable time, in the course of which it was shown that the accident arose by the rails sinking into the earth below the level of the road, the rails not being properly laid on the sleepers. The jury returned a verdict of "accidental death," with a deodand of *5l.* on the carriage.

On Thursday, January 1. 1846, a very serious land slip took place near the Stonehouse station of the Birmingham and Bristol Railway. The down mail train from Birmingham, which was due at Bristol at five o'clock, January 2. had not arrived, and a red light and a bar were placed upon the line above the engine to stop the Birmingham down mail train until the six o'clock Great Western up train had passed. Just at this moment, however, and fortunately before the Great Western engine was attached to the train, the Birmingham mail train came rushing down the steep incline, passed the red light without stopping, and a collision between the two engines was the consequence. The buffers were driven in, the engines dashed off the line, and much injured, but fortunately beyond the alarm necessarily arising from such an accident, the passengers received no injury.

An accident of a fearful and most appalling character happened to a railway train on the South Eastern Railway, on Tuesday morning, January 20. 1846, between Tonbridge

and Penhurst station between 12 and 1 o'clock. The train was passing over a kind of wooden viaduct resting on brick abutments, passing over a branch stream of the river Medway, when the bridge gave way, and the engine and a portion of the train was precipitated into the stream, killing the engine driver, and occasioning a considerable loss of property. The accident is supposed to have happened from heavy rains, the channel of the stream being greatly swollen, and the foundation of the abutments having been injured.

A fatal accident of another kind occurred at the Almond viaduct, on the Edinburgh and Glasgow railway, June, 1845, which created great alarm. It is believed to have arisen from the sleepers of the rails over one of the arches having two much elasticity, which is understood to have since been rectified. An engine of a fast train was suddenly jerked off the rails when going at considerable velocity; the consequence of which was, that the engine was thrown over, and the unfortunate driver was crushed to death. Fortunately, the draw-bar or connecting hooks for attaching the engine to the carriages gave way, leaving the train upon the rails, otherwise the train might have been precipitated over a very high embankment, or over the viaduct, the slight parapet of which could not for an instant have retained the carriages had they been thrown over the rails.

Few accidents which have occurred have been attended with more miraculous preservation than this; and it should afford a useful lesson in all time coming, of the vast responsibility that lies on the planner, constructor, and those in the management of railways, to have a careful eye to the public safety irrespective of expense.

The real cause of this accident has not been officially made public, although an examination of the spot was subsequently made by a government inspector. If the accident arose from too much elasticity of the rails at the spot, it surely admitted of being rectified. It is to be hoped that the chance of recurrence of such an accident is now entirely removed.

Another class of accidents owes their origin entirely to the defects in the construction of the bridges on the line. The accidents arising from these are more fatal to the servants of the railway company than to the public; still, as the preservation of human life, in every case, must be looked to as a part of the executive police of all countries, the servants of railways are as much entitled to have their safety looked after as passengers. I have before shown the want of uniformity of plan which exists in railway works; and in none, perhaps, does it more so than in bridges over the line. It would be desirable to fix, by legal enactment, a standard height. When bridges want elevation, they must be liable to cause accidents, and when once so erected, they remain as a permanent defect on the line.

The danger from the lowness of bridges is seen in the many accidents which have occurred to the

guards on several railways; and it is a painful supposition to the passengers, that a person in the discharge of his duty is liable, in a moment, to be killed on the spot or have his skull fractured by coming in contact with the arch of a bridge. On some lines the guard cannot stand up for a moment without running this risk; and, on some lines, he requires to keep a constant look out, even when sitting on his seat at the top of a carriage. Accidents, from these causes, have occurred in most parts of the kingdom. Not long since, on the Glasgow and Ayr line, one of the guards was killed, when sitting, by his head coming in contact with a bridge; and one of the guards on the Edinburgh and Glasgow railway, when standing at his seat, was nearly killed on the spot from the same cause. It must be apparent that the remedy for such accidents is, when the railway is making, to give a sufficient elevation to the bridges. No expense ought, therefore, to be spared by railway companies to effect this object.

A fatal accident occurred on Friday the 30th January, 1846, on the South Eastern Railway. As the stoker of the engine of the half-past 9 o'clock train from Dover attempted to cross over the luggage van, his head came in contact with one of the bridges, and killed him on the spot.

ACCIDENTS FROM CARRIAGE IMPERFECTIONS.

Another class of accidents take their rise from imperfection in the carriages: —

In the Autum of 1845 an accident occurred on the Edinburgh and Glasgow railway, near to the Polmont station, which might have been productive of serious consequences, had the trains been going at full speed. An axle of one of the carriages gave way, by which one end of the machine was brought to the ground, and smashed in several places. There were no passengers in it. The train in consequence was detained nearly an hour beyond its accustomed time in arriving in Glasgow.

On Saturday night, Oct. 4. 1845, an accident of a very serious kind took place on the Great North of England Railway, about four miles on the York side of Darlington, by which one young married lady received a compound fracture of one of her legs, the other being also broken, and several other passengers were cut and bruised. It appears that at the York station considerable surprise was manifested at the arrival of the engine of the mail train, then overdue, bearing the letter-bags, but without the post-office travelling and passenger carriages.

Upon inquiry if was found that the outer tire of the wheel of a truck, to which the flanch is attached, broke near the nut by which it was fastened to the inner tire. After breaking across at that point the ends rose, and the tire broke a second time at the next nut, and then a portion of the tire and flanch came completely off. The wheel having thus nothing to keep it on the rail, swerved, carrying the axle round in a direction contrary to that in which the carriage was going, till, coming in contact with the carriage, it threw it off the line, and dragged the rest of the

carriages with it. The broken wheel having gone under the carriage, carried the other wheels away, and the carriage was left without any wheels at all, in which state it was found after the accident. The breaking of the outer tire is attributed to its having been put on too hot, and there not having been sufficient allowance made for its contracting properly, so that when it cooled it became too tight. The metal was in consequence defective.

ACCIDENTS FROM FIRE.

The dreadful accident which occurred a few years ago on the railway between Paris and Versailles by the carriages taking fire, and the consequent death of many passengers by burning, could have been easily prevented if a proper system of communication had existed. But the cries and groans of the tortured and the dying were drowned in the rattling of wheels and the puffing of steam. It was not till the whole train was in a blaze that the accident was discovered by those in charge, and the train stopped. To complete the misery of the unfortunate passengers, they were locked up in the carriages. The remedy, indeed, proposed to prevent so serious a catastrophe — namely, the not locking the carriage doors — seems futile; for leaping out of a carriage on fire, going at the rate of 30 miles

an hour, is just the choice of dying in another way.

In France, as in Belgium and on the continent, I can speak from personal knowledge, the railway carriages are very comfortable. Many of them are constructed on the omnibus principle, a number of persons seated in one carriage; but no co-operation had the power of averting this fatal accident. The sparks from the chimney of the locomotive engines are much the same in this country as in France: but need we go to the Continent to seek for examples of the danger from ignition on railways?

On the 28th of May last, on the Liverpool line, a carriage loaded with pigs took fire, and in a few minutes nearly the whole were destroyed.

Again, on the 28th of June, in the half-past five o'clock train, shortly after leaving Greenock for Glasgow, a smell of burning was felt in one of the third class carriages, immediately thereafter the flames burst out on the dress of one of the females, and as the train was at considerable speed, and the wind was high, the utmost consternation prevailed. By the presence of mind and activity of a young seaman, the flames were extinguished, but not before the female's gown was consumed, all to the body and sleeves. This accident occurred from a red-hot cinder ejected from the funnel of the engine.

I have seen several instances of persons nearly in flames from a similar cause in open carriages,

when going rapidly through the air; and it is apparent, if the flames reached any height, the person must be burned, perhaps to death, before the train could be stopped. But how could it be stopped? A whole carriage of third or fourth class passengers might be in flames, and yet unseen either by engineer or guard; nor would even their cries for help be heard. What, then, is to prevent a similar catastrophe in this country, attending the showering of red-hot cinders upon the passengers of the open trains, which occurred in France. It is hardly possible to travel in one of the open carriages without having holes burnt in one's clothes and females' dresses frequently become ignited. When complaint is made as to these annoyances, not unattended with much hazard, the passenger is, perhaps, treated with ridicule, or told it is his own fault in not paying for a better class of carriage. Such is often the spirit of monopoly. In most locomotive engines there is, however, provided wire gauze at the top of the chimney and other means to prevent the escape of the sparks from the furnace; but from being made wide in the meshes when used, to avoid injuring the draught, it proves insufficient for the purpose intended, and it is therefore apparent that other means should be resorted to to obviate this defect.

RAILWAY CARRIAGES.

There can be no doubt that when Government had to introduce a bill into Parliament to protect the rights of the working classes in railway transit, by restricting the rate of charge for third class passengers to a penny per mile, and requiring railway companies to run at least one train having covered third class carriages daily, that much indifference, to say the least of it, must have been shown before any interference took place. But why restrict the penny a mile trains to once a day? why should not carriages of this kind go with every train? Little doubt, however, can be entertained that the construction of railway carriages in this country must be soon entirely remodelled, or at least material changes made on those now in use, before either much comfort or safety will be attained in the cheaper class carriages. It is bad enough to be exposed to the annoyance of dust and risk of losing ones eyes in open carriages, without showers of red-hot cinders, which could be greatly mitigated or entirely prevented by proper mechanical contrivances. Many persons would prefer the open carriages in fine weather, irrespective of the charge, were it not for these annoy-

ances; and in Belgium the waggons or open cars are filled with respectable people, who smoke away at their ease.

In this country the government third class carriages are so hideous and dismal, air and light being nearly both excluded, that they are more adapted for carriage of prisoners than passengers. In some of the third class government carriages there is a wax cloth curtain to draw over the opening, in others a small open window, or rather hole, is left on both sides of the carriage, excluding all view of the country. Till the government regulation the third class were open stalls. The standing carriages are now on some lines called fourth class carriages, and open carriages with seats are called third class carriages. One cannot wonder a third class passenger will rather prefer the external atmosphere to the internal of the close penny a mile carriages. For example, in the third class government carriages on some railways, when all the blinds are drawn up, which often happens in cold weather, the carriage, in daylight, is involved in total darkness. Well may it be asked, is such a carriage a proper conveyance for any one, far less females. Why should not glazed windows be in every carriage? it cannot be the expense of glass; and a penny per mile is surely sufficient to cover such expenses and pay the railway company

properly, and when night trains are used they should be properly lighted. Indeed, it may be questioned if the second and third class passengers are not the most paying, as they are the most numerous class on every railway, and low fares tend clearly to increase numbers, and why should their comfort not be more attended to? In the Belgium railways, which are placed under the management of a government director, who acts under the control of the minister of public works and other functionaries, the rate of charge was formerly higher. When lowered an increase in the number of passengers took place, The charge, I believe, now is: —

1·14 pence per mile first-class carriage,
·93 — ditto second-class ditto,
·56 — ditto third-class ditto,

or about sixpence for ten miles for the third class; while in this country the lowest rate fixed by act of parliament is a penny per mile, being nearly one half more. The first class is nearly 1*s.* and second class 10*d.* for the same distance. This, for 46 miles, would respectively be, about 4*s.* 8*d.*, 4*s.*, and 2*s.* 4*d.*; while the prices in this country are, 8*s.*, 6*s.*, and 4*s.* for the same distance.

The railway companies in this country might do well to take a lesson from their Continental neighbours. The carriages in Belgium consist of three classes, as here; but they possess more comfort and convenience, besides being cheaper. The diligences, or first class, have a sort of vestibule, from which there is ingress to a separate spacious apartment, handsomely fitted up, or the carriage is divided by a narrow passage into two compartments; they are stuffed throughout, and exceedingly comfortable conveyances. The second class, chars-à-banc à glacis, consist principally of one large apartment, entirely closed in at the sides, as the name implies, with glazed windows and well-arranged cushioned seats. The third class, open and covered waggons, do not differ much from the second, having covered seats, but the roofs are sometimes supported at the angles of the carriages by iron rods. The carriages are generally seated to hold 32 passengers, and the doors are usually placed at the ends. Carriages made entirely of iron have recently been introduced on the Belgian railways. Nor need we look to Belgium alone: in France the carriages generally approach to the style of the first class in this country. The second and third class, or *wagon,* far surpass the corresponding classes on

our lines. The second, and commonly the third classes in France are perfectly closed carriages, stuffed, cushioned, and glazed, each class being only a little inferior to the other in decoration. The fares, too, are generally low.

The adoption of such a plan of carriages as those on the Belgian railways, would prevent the risk from the numerous doors in all classes of carriages used in this country. These doors are generally fastened by a common spring latch, which a sudden jerk may break or derange. Few can travel in any of the present carriages without the apprehension of serious accidents even from the people falling out. We are always hearing of hair-breadth escapes; and in a late newspaper the case is mentioned of a child falling out of a carriage unperceived, and how can it be otherwise when there is hardly room to move without coming in contact with a door? I have seen several instances of persons nearly losing their lives from the door on which they leaned suddenly bursting open. Very little ingenuity could remedy this defect; a simple drop bolt inside the carriage in combination with the latch might suffice.

Another very dangerous and improper practice which exists on several lines, and which creates well-grounded alarm to passengers, is, making the

guard step from carriage to carriage by the side steps, holding on by the door handles, in order to collect tickets, and often when the train is going at great speed. The least sudden jerk, or his slipping his hold, would occasion loss of life. Surely such a practice ought to be condemned, for it is as repugnant to common sense as to humanity. The following accident occurred lately from this cause: —

Mr. Glennan, the station-master of the Hull depôt of the Hull and Selby Railway, was thrown from a carriage in the station on Friday morning December 5th, 1845, while, the train was in motion, and, narrowly escaping with his life, had his left arm broken above the elbow. After seeing the 8.55 departure train all right, Mr. G. (as was his custom) got upon the step of a second-class carriage, and held by the open window of the door, to ride down from the platform to the Manor-house-street gate of the station, within two or three yards of which gate he was in the act of stepping down, when the door came open. The speed had at this moment got up to about 10 miles an hour. It is believed that had Mr. G. let go the door open, as it was, he would have received no injury, but the fear of a fall inducing him at the moment to grasp the open door, he was turned a somerset by the velocity of the train, and fell flat on his back, along the outside of the rails, the step of the last carriage striking his left arm as he fell, and fracturing the bone. He was immediately carried home upon a litter, and amputation of the arm was found necessary.

I might proceed farther, detailing accidents arising chiefly from defects which, seemingly,

admit of no great difficulty of rectification; but as the task is ungracious, I shall shortly give a few simple suggestions which occur to me, and which may, perhaps, tend to remedy some of the defects to which I have alluded.

PROPOSALS FOR INCREASE OF SAFETY IN RAILWAY TRAVELLING.

1. I would propose that every locomotive engine should have, in addition to the engineer or driver, and the stoker or fireman, a man or boy to be kept as a look-out, whose duty should be to keep his eye constantly looking behind to the guard, and ready in a moment to communicate to the engineer any signal made. The attention of the latter will thus remain undisturbed to his look-out ahead and to his engine duties; and he will be ready in a moment to slow or reverse the engine, or blow off the steam as necessity may require. This arrangement will, of course, refer to railway trains where the guards are seated on the outside of the carriage; but on the Great Western line, where the guard sits within the carriage, there must obviously be greater necessity for a watch close to the driver

on the engine constantly on the outlook behind. But to insure the safety of a train, the guard should be seated in a position where he could have a commanding view around.

2. That no trains with passengers should proceed without two guards, one stationed on the front, keeping a look out forward, and the other stationed on the rear, keeping a look out behind. Instead of an arrangement of this kind, trains commonly proceed on some lines, sometimes with one, sometimes with two, and sometimes without a guard at all; and sometimes he is in a box where he can see nothing. No special or goods train ought to run on any line without a guard and a look-out.

3. That means should be devised to enable, by signal or otherwise, a free and instant communication to take place between the two guards, and between the guard and the driver. Various propositions have been made to effect this purpose; the idea obviously suggests itself, that a check-string or wire, as in a coach, might be used attached to the arm of the engineer, by which his attention might be instantly arrested, and that a similar plan may be adopted between the two guards, or a wire may be used to strike a bell at the engine. These plans have long since been

proposed by different persons, but have never been carried into effect, as there are some practical inconveniences attending the plan, but which a very little ingenuity would soon master. The subject has recently, from the numerous collisions and carriages running off the rails, received more attention. The necessity has been enforced of providing against danger in the rear as well as in the front, and it has been stated that a guard stationed behind the last carriage would suffice, and who by means of a wire in communication with the engine, might strike a bell in the event of observing any indication of disarrangement, when the engineer would at once stop the train and avert the impending mischief.

The Times newspaper took up this subject, and various communications respecting it appeared in its columns. One writer treats the matter with indifference and as beneath notice: he speaks of the impracticability of working the plan, and founds objections to a wire or cord being laid along the roofs of carriages from its getting entangled, from the variation in the length of the trains when ascending or descending an incline; that false alarms might occur, creating annoyance; and other objections more plausible than real; but, as the old adage has it, "Where

there is a will, there is a way;" experiments might easily be tried to ascertain the simplest manner of accomplishing the object. There is no want of mechanical invention to devise plans; there is only wanting opportunity to test them, which it is as much the duty as the interest of railway companies to afford. One plan is a very simple one, to have a wire in a tube on each carriage, attached by swivels to the wire of the next carriage, in a similar manner as carriage is attached to carriage of a train. By this means wires could be made to communicate without inconvenience, over any length of a train from the guard to a signal bell at the engine-driver. In a similar manner, a flexible tube or speaking trumpet might be attached to each carriage, and quickly joined by screws to any number of carriages, and conversation could be carried on between the guard and the engine-driver; as it is well known the noise of the engine prevents sound from being heard, the attention of parties at each end of the tube might be previously called, by blowing through the tube, and so to strike a bell; a verbal communication could not lead to the misconstruction which a signal might do. By such an arrangement as this, and having the tube made with sufficient elasticity to adapt itself to the

spring of the buffers—a simple and certainly easy mode of communication would at all times exist, and it would have the advantage that at night it would be as useful as in the day.

Among other contrivances for the purpose of affording instant communications with the engine-driver in case of danger is one described as having been not long since exhibited at the Bristol terminus of the Birmingham line, by the superintendent Mr. J. K. Williams. It is a machine like a large box, having on its top a large and sonorous bell, which is struck like the bell of a clock. Within the box is a piece of clock-work precisely similar to that of an alarum, and a red lamp for foggy weather or for night. And from the box, which is intended to be fixed to the nearest carriage to the engine, ropes proceed upon the roof of the various carriages to the guard's box, who, upon perceiving any sign of danger or obstruction of the line, has only to pull the cord and the large bell is instantly rung and a red lamp is shown if at night, or a large board, with the word "stop," flies open, so that the engine-driver's attention is attracted both by sight and sound to the impending danger. The model was highly approved of by several scientific persons. There is a risk that this invention may be too complicated to get into general use.

4. It seems next to certain that the plan of cutting off all power of communication between people in carriages and those who conduct them, cannot be much longer submitted to, as railway travelling becomes extended and rendered more perfect. I have given several examples of the serious and often fatal consequences attendant

on this want of means for passengers communicating with those in charge. The subject is deserving of the most serious consideration to devise a remedy for it. At the present time, should a person be suddenly taken unwell in a railway train, he must remain where he is, happen what may, until he comes to the regular stopping station. As to making himself heard — it is madness to attempt it, for it is like speaking to the wind. It seems most desirable, therefore, for the perfection of railway travelling, that the system proposed of communicating between the guard and the driver should be extended farther; namely, from the occupants of carriages to the guard. Of course, in making this proposition one is immediately met with the objections of the trouble this would give, the unnecessary annoyances and alarms created by passengers, and a host of others; but such are always ready to be made to meet all innovations that create additional trouble or alteration. Still these objections are merely frivolous; because a little unnecessary trouble is created, or at times conceived grounds for alarm foolishly communicated, is the matter to be allowed to remain in the imperfect state it now is? Every carriage might be easily provided with a speaking tube or wire signal to the

guard. But what would be the use of the signal, if the guard could not get to the carriage? and certainly passengers would rather put up with the present system, bad as it may be, than cause the guard to run the risk of losing his life, by scrambling from carriage to carriage, holding on by the handles of the doors, when the train is proceeding with the utmost velocity.

5. This brings into view the consideration, whether railway carriages could not be constructed with all, if not more, of the conveniences they now possess, and still afford a free passage from end to end of a train for the guard. There are several ways this might be done. The carriages might be constructed in the form of a parallelogram, both longer and wider than at present, divided into two compartments, with a free passage, as in a canal passage-boat, from end to end of them. The carriages of the Great Western from their breadth easily admit of the experimental trial of such a construction of carriages — a broad carriage affording more facilities for an arrangement of this kind. In carriages constructed with an intermediate centre passage or vestibule, the two side compartments might be divided as cabins, the passengers in each sitting *vis-à-vis*, or otherwise; the entrance to

the vestibule being at each end of the carriages, like those carriages on the Belgian railways already noticed.

By means of the arrangement of the centre passage I propose, a free communication could exist between the passengers and the guard, as, on a signal being given, the number of the carriage would be intimated and the carriage visited: any false signal made should be punishable, which would prevent annoyance being given. In having thus the safe means of going from one end of a train to the other (for a gang-way could be formed between the carriages), the check-tickets could be at any time collected, thus obviating the general present detention of the passengers for this purpose: this would be a great benefit to passengers at many stations.

It appears to me that it would be desirable to experimentally try an entire alteration and re-modelling of railway carriages, at least those for second and third class passengers; and until this is done probably neither safety nor comfort will be obtained: the foreign construction of carriages seems desirable and advantageous to be tried. No carriage, in my opinion, can be deemed a safe mode of conveyance when so many doors exist as in the present railway carriages; and where, even

at the most rapid speed, as has been shown, accidents occur from persons leaning on them falling out: besides, they create constant apprehensions: for, should the convenience of getting quickly out be put in comparison with safety? Most of the doors of the railway carriages are, as already mentioned, merely fastened with a spring latch, which is liable to derangement. On the Blackwall Railway an excellent precaution is adopted, of having a drop bolt without the door, which is let into a socket. This plan is adopted on the Continent.

There can be little doubt, as the railway system becomes almost the only mode of travelling, and as long journeys must frequently be taken by it, more attention will be paid to the construction of the carriages, and the comfort of all classes of passengers, than at present. If the numerous accidents on railways, proving so injurious to limbs and life, are examined, it will be found that the legs of the unfortunate passengers most frequently suffer — many cases of fracture and compound fracture, near the knee, having taken place, from the legs being driven or jammed upon the opposite seats. Had the passengers been sitting in a reverse position, with seats in the direction of the length of the carriage, as in an

omnibus, many of these injuries might have been averted; and it seems most desirable that this plan of carriage should be tested by experience: passengers must be fully as comfortable, if not more so, than when sitting with their backs or faces to the engine.

The Great Western has been the first railway to introduce an improved carriage on the apartment principle: this kind of carriage has as yet been confined to pleasure parties; but were carriages used in this form to run regularly on the line, at a moderate rate of charge, they would be preferred. Not only carriages for parties, but invalid carriages, carriages for refreshments, and even smoking carriages, with side seats for those who like it, with a box for the attendant, should be provided on all direct or trunk lines of communication; and family carriages could be made as separate cabins, as in a steamboat, with every convenience, for those who chose to pay for or engage them. An attendant should accompany the train merely to look after the comforts of the passengers, so as the guard should on no account be obliged to leave his station on the outlook — his duty being strictly confined to the charge of the train and communicating with and directing the driver.

6. On those railways where, from the narrow gauge, there cannot exist the same facility of constructing an intermediate passage through the carriages without encroaching too much on them, and the accommodation of the passengers, some other plan may be adopted to attain this object— where the width between the lines of way is sufficient, which it always ought to be, a terrace, or platform, from 18 to 20 inches broad, railed on the outside, may be constructed outside the carriages, where the present step is — made in such a manner as not to interfere with the access to the carriage doors. On the platform the attendant or guard could walk, from end to end of a train, without danger to himself: however, it must be obvious, that the gauge of the rails, and the intermediate space between the lines, must regulate many of the particulars, pointing out the prudence of a careful revision of all these points by rival railway companies; for it is only by competition that perfection is likely to be attained; and the reason why more ingenuity has not as yet been displayed in railway carriages arises, perhaps, from the near-sighted policy of making the cheap carriages as uncomfortable as possible to drive passengers into the disagreeably close, air-tight, and expensive first-class carriages.

7. For the safe transit of locomotive carriages, it seems desirable that every railway should possess an electric telegraph, by which the starting of every train may be announced from end to end of the line: this telegraph, having the means of communicating with intermediate stations, might be farther extended, when the distance between stations was great, so that in the event of any accident happening to the engine, the power of communicating notice of it might be made in both directions. If such a plan was in existence, how many fatal accidents might have been averted!

8. A uniform code of signals should be used on all railways in this country. In cases of fog such signals should be provided so as to prevent the possibility of mistakes. Each station should have properly understood self-acting alarums, operated on as the engine reaches the stations, and having the means of setting them as required. In addition to the common steam-whistle, which signal is apt to be misunderstood, a gong, or powerful bell, might be advantageous for engines in the case of fogs, darkness, or extreme danger. The plan has been adopted with the engines on the Great Western Railway, of having two steam-whistles of different sounds: one of these is used as the general alarum,

or signal, the other for the guard. This plan might be carried much farther, with great advantage, by the up-trains having one sound of whistle and the down-trains another: it would form an excellent fog and night signal. At the present time, on most railways the shrill sound of the steam-whistle is used chiefly to warn the people working on the lines and the station-keepers of the approach of the trains; and as the sound in calm weather is heard at several miles distance, the alarm is very useful; but as the sounds of the steam-whistles are so alike, the signal is of little use in telling which way the train is going; this is judged of merely from the general effect of the noise the engine makes, which must be admitted to be very open to misconstruction, and at stations where many lines meet the noise creates much confusion. A series of signals arranged with steam-whistles of different sounds, or by the combining of the sounds of two or three, the meaning being known at stations, from the distance it would be heard at, might form useful alarm-signals by day or night.

9. From the accidents which have been noticed, especially the one at the Camden Town station, it seems desirable that experiments were tried of the best mode of signal-lights for foggy weather,

Among many inventions proposed for this purpose are

Giscard's Improved Railway Signal Lamps. Since the proprietor made his invention public, he has much improved the practical details. The following are its peculiar advantages: — The same apparatus serves for both night and day. Up-trains and down-trains are alike informed by his system of signals, of all of which they ought to be informed; of accidents on either line; how long since the last train passed that signal post; whether any train is to stop, slacken its speed, reverse its direction, or go on to a siding. In the case of crossings, a signal can be given that two trains are approaching, and signify which must stop, and which must go on. In fact, a whole code of instructions can be perfectly signalled. No supernumerary signals are in any case required. Another great advantage of this lamp is, that its colours and arrangement being in perfect congruity with the signals already in use, the signal-men will immediately comprehend the new system. The invention will be submitted to the consideration of the proper government officials. By night and in foggy weather, these signals are sufficiently brilliant to be seen for a considerable distance, and their cost is very trifling.

Forsyth's patent railway signals likewise appear to be a simple and useful invention He suggests that each engine should carry a different diagram of lights; and by a signal-post with lamps arranged, a corresponding signal could be made to that of the engine by closing one or more of the lamps. Thus an engine-driver, knowing the diagram of the light he carries, and seeing a corre-

sponding signal at a station, would know that it was intended for his guidance, while the persons at the station would be apprised of the train which was approaching.

10. On the Belgian railways each train carries with it two guards, who are provided with bugles. In starting, when the first bell has rung, the passengers take their seats; and, at the second bell, the guard at one end sounds his bugle, which is answered by the other. This lets the passengers know that all is right, and the train proceeds. This plan inspires a degree of confidence that the silent system cannot, while those bugles, in case of emergency, become a useful alarm signal.

11. It has been suggested by some writers that were the engine-driver placed in front of the engine instead of behind it, it would induce, on his part, more circumspection and caution to guard against accidents; but this is a mere assumption; for surely the engine-driver is already too much exposed to attend properly to his duty. It would be a simple matter to afford him shelter without interfering with his responsibility; and if it is expected that a higher class of engineers are to enter upon this service, so important for public safety, it can only be by increasing their

own safety and comfort, and giving them every encouragement consistent with the proper discharge of duty.

12. As the railway gauge is now under the consideration of Government, the result must soon be known to the public. The commissioners have reported in favour of the advantages to be derived from a standard gauge over the kingdom; and that that should be the narrow one: although now attended with difficulty to carry out a uniform gauge, it obviously presents many advantages in railway traffic. This plan I have long entertained, but it is a question of most serious importance, when attempting now to carry out this plan, if, in restricting railroads to the narrow gauge, it will not militate against future railway improvements.

I would also propose to extend the arrangement of uniformity still further, and that there shall be a fixed standard rule, over the whole kingdom, for the weight of rails where locomotive engines are run; that no engine, tender, or luggage van, or passenger carriage, shall have fewer than six wheels, if to be run at quick speed (on many railways the engine, as well as carriages are still used with four wheels); that defined limits be fixed both as to curves and gradients, as also for the height and length of

tunnels, elevation, and width of bridges, spaces between the lines of rails, and between the rails and embankments (the fixing of these points would tend to increase public confidence in railway transit); that it be made a general regulation that every railway station be provided with a bridge or a culvert, that passengers, in passing from the station-house to the other side of the line, may not require to walk across the line of rails; that the maximum speed of trains, on each particular line, be fixed by the Railway Board in accordance with the gradients, curves, tunnels, and viaducts existing on the line. The adoption of fixed rules for these points would tend to prevent accidents; it would also be advantageous for the public safety were a reasonable time allowed at stations when taking up and putting down passengers, instead of the present prevalent system of hurry and confusion.

13. That some simple plan be devised by which the guard could instantly disengage the carriages or luggage-van from the engine, and the carriages from each other: the utility of this in case of accidents must be obvious. I would also recommend that the links of the draw-bars or connecting hooks between the carriages be made in such a manner that they would only bear a certain

strain laterally without breaking, or that the carriage, by some contrivance, when canted over, be separated from the others, without dragging them with it.

14. That, to guard against accidents from fire, experiments be tried, to ascertain if it be not possible to keep up sufficient draught in the engine chimney, and yet get entirely rid of sparks from it. Till this is got the better of, there will always exist considerable danger, both to the trains and to the ignition of any thing of a combustible nature on the sides of the railway. One plan might be tried to prevent the escape of red-hot cinders from the chimney, — namely, the whole chimney to be enclosed in a copper wire screen, elevated sufficiently above the top to allow the free escape of the smoke; any sparks or cinders would thus be retained within the screen and conducted to the ground. In a similar way, dust or ashes from the furnace might be retained from being blown about, and conveyed by a spout to the ground.

15. That no railway company be permitted to make contracts with the engine-driver to run the engine by contract, — the evil effect of which I have fully pointed out. (See *Boilers.*)

16. That, at every railway station, a book be

kept, into which complaints by the passengers may be entered. This would be a proper check on the servants of the railway company; and the manager could investigate the matter without detaining the passengers. It is not probable that any complaint would be made unless there was sufficient cause.

17. That railway inspectors be appointed by Government, for reasons previously given, for every large town in the United Kingdom where railway termini are centered; and that, as at present, a most careful survey be made of the whole line before it is opened for railway traffic. That these inspectors should have ample powers given them to inquire into the mode of management and keeping in repair of the railroad, the engine, and carriages, — to inquire into complaints as to time, causes of accidents, and every point connected with the public safety. Reports may be made, from time to time, to the railway board.

18. That on all main trunk lines, and on railways between large towns, where the goods traffic is of much extent, it would prove most advantageous for the public safety that a third line of rails be laid down, to which the goods traffic might be entirely confined, keeping the passenger carriages

there is a will, there is a way;" experiments might easily be tried to ascertain the simplest manner of accomplishing the object. There is no want of mechanical invention to devise plans; there is only wanting opportunity to test them, which it is as much the duty as the interest of railway companies to afford. One plan is a very simple one, to have a wire in a tube on each carriage, attached by swivels to the wire of the next carriage, in a similar manner as carriage is attached to carriage of a train. By this means wires could be made to communicate without inconvenience, over any length of a train from the guard to a signal bell at the engine-driver. In a similar manner, a flexible tube or speaking trumpet might be attached to each carriage, and quickly joined by screws to any number of carriages, and conversation could be carried on between the guard and the engine-driver; as it is well known the noise of the engine prevents sound from being heard, the attention of parties at each end of the tube might be previously called, by blowing through the tube, and so to strike a bell; a verbal communication could not lead to the misconstruction which a signal might do. By such an arrangement as this, and having the tube made with sufficient elasticity to adapt itself to the

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on this want of means for passengers communicating with those in charge. The subject is deserving of the most serious consideration to devise a remedy for it. At the present time, should a person be suddenly taken unwell in a railway train, he must remain where he is, happen what may, until he comes to the regular stopping station. As to making himself heard — it is madness to attempt it, for it is like speaking to the wind. It seems most desirable, therefore, for the perfection of railway travelling, that the system proposed of communicating between the guard and the driver should be extended farther; namely, from the occupants of carriages to the guard. Of course, in making this proposition one is immediately met with the objections of the trouble this would give, the unnecessary annoyances and alarms created by passengers, and a host of others; but such are always ready to be made to meet all innovations that create additional trouble or alteration. Still these objections are merely frivolous; because a little unnecessary trouble is created, or at times conceived grounds for alarm foolishly communicated, is the matter to be allowed to remain in the imperfect state it now is? Every carriage might be easily provided with a speaking tube or wire signal to the

guard. But what would be the use of the signal, if the guard could not get to the carriage? and certainly passengers would rather put up with the present system, bad as it may be, than cause the guard to run the risk of losing his life, by scrambling from carriage to carriage, holding on by the handles of the doors, when the train is proceeding with the utmost velocity.

5. This brings into view the consideration, whether railway carriages could not be constructed with all, if not more, of the conveniences they now possess, and still afford a free passage from end to end of a train for the guard. There are several ways this might be done. The carriages might be constructed in the form of a parallelogram, both longer and wider than at present, divided into two compartments, with a free passage, as in a canal passage-boat, from end to end of them. The carriages of the Great Western from their breadth easily admit of the experimental trial of such a construction of carriages — a broad carriage affording more facilities for an arrangement of this kind. In carriages constructed with an intermediate centre passage or vestibule, the two side compartments might be divided as cabins, the passengers in each sitting *vis-à-vis*, or otherwise; the entrance to

the vestibule being at each end of the carriages, like those carriages on the Belgian railways already noticed.

By means of the arrangement of the centre passage I propose, a free communication could exist between the passengers and the guard, as, on a signal being given, the number of the carriage would be intimated and the carriage visited: any false signal made should be punishable, which would prevent annoyance being given. In having thus the safe means of going from one end of a train to the other (for a gang-way could be formed between the carriages), the check-tickets could be at any time collected, thus obviating the general present detention of the passengers for this purpose: this would be a great benefit to passengers at many stations.

It appears to me that it would be desirable to experimentally try an entire alteration and remodelling of railway carriages, at least those for second and third class passengers; and until this is done probably neither safety nor comfort will be obtained: the foreign construction of carriages seems desirable and advantageous to be tried. No carriage, in my opinion, can be deemed a safe mode of conveyance when so many doors exist as in the present railway carriages; and where, even

at the most rapid speed, as has been shown, accidents occur from persons leaning on them falling out: besides, they create constant apprehensions: for, should the convenience of getting quickly out be put in comparison with safety? Most of the doors of the railway carriages are, as already mentioned, merely fastened with a spring latch, which is liable to derangement. On the Blackwall Railway an excellent precaution is adopted, of having a drop bolt without the door, which is let into a socket. This plan is adopted on the Continent.

There can be little doubt, as the railway system becomes almost the only mode of travelling, and as long journeys must frequently be taken by it, more attention will be paid to the construction of the carriages, and the comfort of all classes of passengers, than at present. If the numerous accidents on railways, proving so injurious to limbs and life, are examined, it will be found that the legs of the unfortunate passengers most frequently suffer — many cases of fracture and compound fracture, near the knee, having taken place, from the legs being driven or jammed upon the opposite seats. Had the passengers been sitting in a reverse position, with seats in the direction of the length of the carriage, as in an

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